U.S. DEPARTMENT OF ENERGY

Used Oil Management and Beneficial Reuse Options to Address Section 1: Energy Savings from Lubricating Oil Public Law 115-345

Report to Congress
December 2020

United States Department of Energy
Washington, DC 20585

Disclaimer

Message from the Secretary

This Congressional Report, pursuant to Public Law 115-345, updates the *Used Oil Re-refining Update of the 2006 Used Oil Re-refining Study to Address Energy Policy Act of 2005, Section 1838,* and addresses efforts underway at the U.S. Department of Energy, in cooperation with the U.S. Environmental Protection Agency and the Director of the Office of Management and Budget. This report also provides a coordinated Federal strategy to increase the beneficial reuse of used lubricating oil.

Pursuant to statutory requirements, this report is being provided to the following Members of Congress:

- **The Honorable Michael R. Pence**
  President of the Senate

- **The Honorable Nancy Pelosi**
  Speaker of the House of Representatives

- **The Honorable Lisa Murkowski**
  Chairman, Senate Committee on Energy and Natural Resources

- **The Honorable Joe Manchin**
  Ranking Member, Senate Committee on Energy and Natural Resources

- **The Honorable Eddie Bernice Johnson**
  Chairwoman, House Committee on Science, Space and Technology

- **The Honorable Frank Lucas**
  Ranking Member, House Committee on Science, Space and Technology

- **The Honorable Frank Pallone**
  Chairman, House Committee on Energy and Commerce

- **The Honorable Greg Walden**
  Ranking Member, House Committee on Energy and Commerce

- **The Honorable Richard Shelby**
  Chairman, Senate Committee on Appropriations

- **The Honorable Patrick Leahy**
  Vice Chairman, Senate Committee on Appropriations

- **The Honorable Lamar Alexander**
  Chairman, Subcommittee on Energy and Water Development
  Senate Committee on Appropriations

- **The Honorable Dianne Feinstein**
  Ranking Member, Subcommittee on Energy and Water Development
  Senate Committee on Appropriations

- **The Honorable Nita M. Lowey**
  Chairwoman, House Committee on Appropriations

- **The Honorable Kay Granger**
  Ranking Member, House Committee on Appropriations

- **The Honorable Marcy Kaptur**
  Chairwoman, Subcommittee on Energy and Water Development, and Related Agencies
  House Committee on Appropriations

- **The Honorable Mike Simpson**
  Ranking Member, Subcommittee on Energy and Water Development, and Related Agencies
  House Committee on Appropriations

If you have any questions or need additional information, please contact Mr. Shawn Affolter, Deputy Assistant Secretary for Senate Affairs or Mr. Christopher J. Morris, Deputy Assistant Secretary for House Affairs, Office of Congressional and Intergovernmental Affairs, at (202) 586-5450, or Ms. Katie Donley, Deputy Director of External Coordination, Office of the Chief Financial Officer, at (202) 586-0176.

Sincerely,

Dan Brouillette

List of Acronyms

ACC	American Chemistry Council
AEO2019	Annual Energy Outlook 2019
AOCA	Automotive Oil Change Association
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
ATIEL	Association Technique de l'Industrie Européenne des Lubrifiants
Bbl	Barrel
BOD	Biological Oxygen Demand
Btu	British Thermal Unit
CAA	Clean Air Act
CAFE	Corporate Average Fuel Economy
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CISWI	Commercial and Industrial Solid Waste Incineration
CO	Carbon Monoxide
CONOU	Consorzio Nazionale per la Gestione
CPG	Comprehensive Procurement Guideline
CWT	Centralized Waste Treatment
DIFM	Do-It-For-Me
DIY	Do-It-Yourself
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EHC	Environmental Handling Charge
EIA	U.S. Energy Information Administration
EISA	Energy Independence and Security Act
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPR	Extended Producer Responsibility
EU	European Union
EV	Electric Vehicle
GEIR	Groupement Européen de l'Industrie de la Régénération
GWP	Global Warming Potential
HAP	Hazardous Air Pollutants
H.R.	House Resolution
HSFO	High Sulfur Fuel Oil
IC	Internal Combustion
IFEU	Institut für Energie- und Umweltforschung GmbH
IMO	International Marine Organization
ISO	International Organization for Standardization
LCA	Life Cycle Analysis

MARPOL 73/78	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL: Marine Pollution)
MBPD	Thousand Barrels Per Day
MDO	Marine Diesel Oil
MJ	Megajoule
MM	Million
MMBtu	Million British Thermal Unit
MMG	Million Gallons
MMGPY	Million Gallons Per Year
MPG	Miles Per Gallon
NESHAP	National Emission Standards for Hazardous Air Pollutants
NGO	Non-Governmental Organization
NH_x	Reduced Inorganic Nitrogen
NHTSA	National Highway Traffic and Safety Administration
NOLN	National Oil Lube News
NORA	National Oil Recyclers Association
NOx	Nitrous Oxides
NREL	National Renewable Energy Laboratory
NUOMAAC	National Used Oil Material and Antifreeze Advisory Council
OEM	Original Equipment Manufacturer
OPEC	Organization of the Petroleum Exporting Countries
OSWRO	Off-site Waste Recovery Operations
P.L.	Public Law
PCB	Polychlorinated Biphenyl
PFO	Processed Fuel Oil
PM	Particulate Matter
PPM	Parts Per Million
RCRA	Resource Conservation and Recovery Act
RES	Rock Energy Systems
RFO	Recycled Fuel Oil
RMAN	Recovered Materials Advisory Notice
RRBO	Re-refined Base Oil
RRF	Resource Recovery Facility
SAE	Society of Automotive Engineers
SECA	Sulfur Emission Control Area
SO_2	Sulfur Dioxide
SPCC	Spill Prevention Control and Countermeasures
SSDE	Service Station Dealer Exemption
SUV	Sport Utility Vehicle
Tcf	Trillion Cubic Feet
TSCA	Toxic Substances Control Act
UAE	United Arab Emirates
UEIL	Union of the European Lubricants Industry

UK	United Kingdom
UL	Underwriters Laboratories
UMO	Used Motor Oil
U.S.	United States
UOMS	Used Oil Management Standards
UORC	Used Oil Refining Coalition
VGO	Vacuum Gas Oil
VMT	Vehicle Miles Traveled
WFD	Waste Framework Directive
wt.	Weight
WTI	West Texas Intermediate

Executive Summary

On December 21, 2018, Congress approved Public Law (P.L.) 115-345 directing the Secretary of Energy, in cooperation with the Administrator of the U.S. Environmental Protection Agency (EPA) and the Director of the Office of Management and Budget (OMB), to review and update a report on the energy and environmental benefits of the re-refining of used lubricating oil that had been prepared pursuant to Section 1838 of the Energy Policy Act of 2005. That report,[1] titled "Used Oil Re-refining Study to Address Energy Policy Act of 2005, Section 1838," dated July 2006, was "a study of the energy and environmental benefits of the re-refining of used lubricating oil… including recommendations of specific steps that can be taken to improve collections of used lubricating oil and increase re-refining and other beneficial re-use of such oil."

P.L. 115-345 directed the U.S. Department of Energy (DOE) to consult with relevant Federal, State and local agencies and affected industry and stakeholder groups, to update data that was used in preparing the 2006 report, and prepare and submit to Congress a coordinated Federal strategy to increase the beneficial reuse of used lubricating oil that is consistent with national policy as established pursuant to Section 2 of the Used Oil Recycling Act of 1980 (P.L. 96-463). Further, P.L. 115-345 stipulates that the strategy was to address measures needed to (a) increase the responsible collection of used oil, (b) disseminate public information concerning sustainable reuse options for used oil, and (c) promote sustainable reuse of used oil by Federal agencies, recipients of Federal grant funds, entities contracting with the Federal Government and the general public.

This document is the updated report prepared by DOE in response to P.L. 115-345. To gather the information needed to prepare this document, DOE met on multiple occasions with representatives of key stakeholder groups within the used oil sector to gather input on the status of the industry. In addition, DOE held a public meeting on October 16, 2019, at DOE offices in Washington, DC, to engage a wider variety of stakeholders and gather additional input (see Appendix H for a list of attendees). The meeting included 73 individuals from more than 50 organizations and companies in attendance either in-person or via WebEx. The information gathered, together with findings from independent research carried out by DOE staff, were used to update the 2006 report.

This updated report includes a number of recommended actions to "improve collections of used lubricating oil and increase re-refining and other beneficial re-use of such oil." A separate document (Attachment 1 to this report) outlining a coordinated Federal "strategy to increase the beneficial reuse of used lubricating oil" has been prepared for delivery to Congress, as directed in P.L. 115-345.

[1] DOE, 2006, Used Oil Re-refining Study to Address Energy Policy Act of 2005, Section 1838, https://fossil.energy.gov/epact/used_oil_report.pdf.

The used oil recycling sector in the United States is responsible for the collection and treatment of used oils, including the re-refining of used oils into lubricant base stocks and the reprocessing to fuels and other valuable petroleum-derived products. Each stakeholder group within the industry has unique perspectives on the priorities for Federal Government policy and potential actions to encourage more efficient recovery and re-use of used oil. In response to increasing demand for higher quality lubricants over the last decade, domestic re-refiners have increased used oil re-refining capacity and seek to increase the overall volumes of used oil collected, creating opportunities to further produce and market their re-refined lubricant base stock products. Used oil collectors, a stakeholder group which has undergone consolidation since the 2006 report was published, seek to find ways to increase collection efficiency and improve profit margins that are being squeezed by lower oil price environments. Used oil generators and collectors hope to avoid the costs of used oil contamination due to unknown do-it-yourself sources and maintain flexibility in their ability to burn used oil as a fuel substitute on their own premises. Crude oil refiners producing virgin lubricant base stocks want to maintain market access and avoid the implementation of policies that distort a level playing field in the marketplace and do not favor flexible options for customers in sourcing base stocks.

Primary stakeholders all agree on a broad set of recommendations to improve market performance and identify industry trends: (1) recognizing the benefits of increasing used oil collections, (2) reducing improper disposal by dumping or adding to landfills, and (3) encouraging the collection and publication of improved and regularly updated industry data. Accurate analysis of the used oil marketplace in the United States is currently hindered by a lack of detailed data regarding the volumes of oil lost in use, the volumes collected and remaining uncollected, volumes that are improperly disposed of, volumes burned legally, and volumes processed and re-used but ultimately not re-refined.

Another area of agreement is on the need for improved methods for detecting and preventing used oil contamination with toxic constituents (e.g., poly-chlorinated biphenyls), which complicate the recycling process, as well as the need to make certain that environmental regulations both encourage the collection and re-use of used oil and protect the environment.

Several factors will influence the used oil re-refining sector in the near future.

- As automotive and industrial technologies continue to evolve, demand for higher performing lubricants will likely grow. Lubricant base stocks (organized by industry into groups) have varying characteristics, uses, performance, and are constantly engineered to meet changing market demands.
- Soon-to-be implemented United Nations International Marine Organization regulations limiting marine bunker fuel (diesel fuel used in ship engines) sulfur content is likely to result in a global trend of declining sulfur-heavy fuel markets. Used oil sources tied to high sulfur fuel will see lower used oil values and in tandem, the value of used oil in traditional fuel markets will likely decline.

- The expected continued robust domestic supply of low-priced natural gas will continue to act to reduce demand for used oil as a heating or processing fuel.

These external factors are likely to enhance the dynamic nature of the domestic used oil sector, making it even more important for the stakeholders to have access to accurate data and for there to be policies in place to support a healthy and robust used-oil collection and re-use industry.

In 2018, domestic consumption of motor and industrial lubricants product marketplace was estimated to be approximately 2.47 billion gallons. Of this consumed volume, greater than 1.37 billion gallons of used oil was generated by automotive and industrial use sectors for possible collection and re-use. The volume of used oil unaccounted for at the source (i.e., burned in space heaters by generators, recycled onsite or disposed of in some other manner, including "do-it-yourself" (DIY) disposal in landfills or dumped into storm sewers, etc.) was estimated to be 429 million gallons (MMG) or about 31 percent of the used oil generated. This percentage is estimated to have remained fairly constant, in the 30-35 percent range, over the past decade. Based on available data, it is estimated that between 80 and 120 MMG of collected used oil is legally burned annually in space heaters by used oil generators. This amounts to between 18 and 28 percent of the estimated volume of used oil collected in 2018. While between 309 and 349 MMG per year of used oil remain unaccounted for, the accuracy of these estimates is problematic due to the lack of reliable data (in particular with regard to estimates of loss in use, volumes of used oil collected and volumes burned). However, it is clear that there is significant potential for improving the overall efficiency of used oil collection.

Since the publication of the 2006 report, eight new life cycle analysis (LCA) studies were published on used oil dispositions. Four of these studies were determined to be most reflective of current U.S. technologies and industry applications. Studies conducted by the Institute for Energy and Environmental Research in 2018 and Safety-Kleen in 2014 compare the impacts of re-refining used oil against refining virgin oil from crude. These studies find the energy and environmental impacts for re-refining are nearly an order of magnitude less than producing lubricant base stocks from virgin crude oil. Studies by the American Petroleum Institute find that when consequential upstream impacts and product shortfalls are incorporated, used oil re-refining impacts are less favorable and, in some scenarios, unfavorable compared to employing used oil in a fuel disposition while refining virgin base stocks from crude to balance product demands. Neither primary waste management strategy dominates the other in any of the major LCA impact categories, suggesting that each strategy has tradeoffs.

Conservation and recycling of the Nation's used oil (1) extends the life of U.S. crude oil resources, (2) reduces the likelihood of improperly disposed of used oil making its way into the environment to contaminate soil and water, and (3) is energy efficient, as it can take less energy to recycle used oil than to create new lubricating oil from virgin crude oil. Further, used oil recycling supports thousands of direct and indirect jobs, generates tax revenue, and helps provide consumers with a range of economical product choices.

To support a proposed Federal strategy "to increase the beneficial reuse of used lubricating oil," a total of 18 individual opportunities were identified for Federal action to improve the collection of used lubricating oil and increase re-refining and other beneficial re-use of such oil. These are described in Table 1 and Section XII of this report and grouped into four categories: Information Exchange and Outreach, Data Collection and Research, Data Analysis, and Policy Development. Upon further guidance from Congress, DOE would have a coordinating role, as appropriate, in implementing the recommended actions.

Table of Contents

I. Legislative Language

This report responds to legislative language set forth in Public Law 115-345 to direct the Secretary of Energy to review and update a report on the energy and environmental benefits of the re-refining of used lubricating oil. The law states:

SECTION 1. ENERGY SAVINGS FROM LUBRICATING OIL

Not later than 1 year after the date of enactment of this Act, the Secretary of Energy, in cooperation with the Administrator of the Environmental Protection Agency and the Director of the Office of Management and Budget, shall—

(1) review and update the report prepared pursuant to Section 1838 of the Energy Policy Act of 2005;

(2) after consultation with relevant Federal, State, and local agencies and affected industry and stakeholder groups, update data that was used in preparing that report; and

(3) prepare and submit to Congress a coordinated Federal strategy to increase the beneficial reuse of used lubricating oil, that—

(A) is consistent with national policy as established pursuant to Section 2 of the Used Oil Recycling Act of 1980 (Public Law 96–463); and

(B) addresses measures needed to—

(i) increase the responsible collection of used oil;

(ii) disseminate public information concerning sustainable reuse options for used oil; and

(iii) promote sustainable reuse of used oil by Federal agencies, recipients of Federal grant funds, entities contracting with the Federal Government, and the general public

Approved December 21, 2018.

II. Overview

Lubricating and process oils refined from crude oil enable our standard of living by "greasing the wheels"—literally and figuratively—of modern life. While the hydrocarbon fuels supplying the machinery being lubricated by these oils are consumed, a good portion of the lubricants are not. Their highly refined hydrocarbon molecules can be put to use again if captured, re-refined, and recycled. Conservation and recycling of used oil extends the life of our national crude oil resources, reduces the likelihood of improperly disposed of used oil making its way into the environment to contaminate soil and water, and is energy efficient, as it can take less energy to recycle used oil than to create new lubricating oil from virgin crude oil.

The used oil recycling industry is built on the fact that there are also economic benefits in collecting, processing, and re-refining used oil to provide lubricating oil base stocks or base oils and other products for a wide variety of consumers. Used oil recycling supports thousands of direct and indirect jobs, generates tax revenue and helps provide consumers with a range of economical product choices.

Industry Overview and Changes since 2006 Report

The United States is responsible for 21 percent of total worldwide lubricant demand and its per capita lubricant demand is more than double the next closest region at 7.6 gallons per year. The lubricant market in the United States has hovered around 2.5 billion gallons since 2014, with approximately half of all products provided to the automotive sector and the other half to industrial applications.

Lubricant Quality Changes: As automotive and industrial technologies continue to evolve, demand for higher performing lubricants has grown. Higher performance modern lubricants can directly contribute to the improved environmental performance of operating mechanical systems. Lubricant quality has been improved through increased use of high-performance additives and the wider introduction of "synthetic lubricants."

The American Petroleum Institute (API) classifies five lubricant base stock groups—Groups I, II/II+, III/III+, IV, and V—as determined by the amounts of saturated compounds and sulfur in the oil and its viscosity (further explained in Section III and Appendix A). North American production capacity of API Group II has grown while production of Group I has declined. North American production volume for the higher performance specification Group III/III+ lubricants remains relatively small, only 2 percent of U.S. base stock lubricant production, primarily due to economics. Domestic demand for these higher performance lubricants is met through imports. Today, more than 80 percent of U.S. imports of Group III and Group III+ base stocks come from South Korea, Indonesia, and the Middle East. Both crude oil refiners and used-oil re-refiners recognize opportunities for growing domestic production capacity to meet an expected increase in demand for Group III/III+ lubricants as automobile engines evolve to meet improved fuel economy and lower emissions standards.

As the average quality level of the automotive lubricating oil in the system rises, the volumes of higher quality used motor oil collected should continue to rise and its use as a feedstock for re-refinement to higher quality base stocks could become a more economically appealing option compared to production from virgin crude oil base stocks.

Near-Term Market Changes: In the United States, only about 30 percent of collected used oil of all types is re-refined into lubricant base stocks. The rest is processed or re-refined into other products, including fuel oil, and some raw used oil is burned as fuel for heating or in industrial or marine applications. However, since the 2006 report was published, rapid growth in the supply of natural gas from unconventional gas plays and associated gas from tight oil plays has lowered natural gas prices, making it a very competitive fuel to used oils. The growth in low price natural gas supply has impacted the used oil re-refining sector by reducing the demand for used oil as a fuel by certain end users (e.g., asphalt plants). In response, the used oil industry has increased re-refining capacity.

An emerging factor which will exert some economic influence over used oil economics are the United Nations International Marine Organization (IMO) regulations, implemented January 2020, limiting marine bunker fuel (fuel used in ship engines) sulfur content to 0.5 weight (wt.) percentage from the current 3.5 wt. percentage in an effort to reduce exhaust emissions. There will be a global trend of declining demand for high sulfur heavy fuel and these regulations pose a significant challenge for global petroleum refineries: how to increase the supply of low sulfur products for use in marine applications and minimize the output of high sulfur oils. Used oil market prices which are tied to high sulfur fuel will see lower values. With the lower prices for fuel oils, used oil collectors and processors will come under pressure as their revenues tied to fuel oil prices decline. Conversely, base stock values could see an upward trend as the low sulfur refining components competing within the lubricant base oil product category (desulfurized vacuum gas oils) see higher value as components for production of low sulfur bunker fuel.

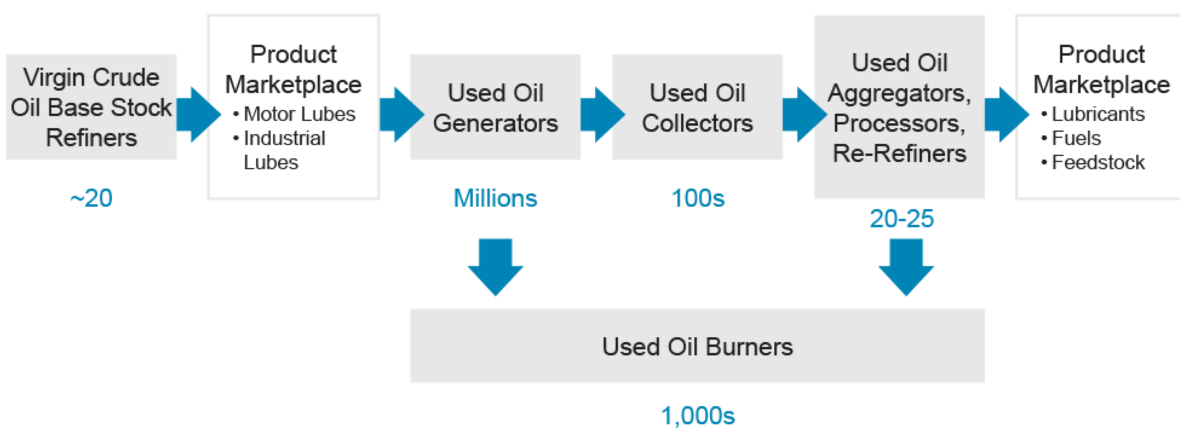
Used Oil Sector Stakeholders: The used oil sector in the United States includes five primary stakeholder categories: Generators, Collectors, Aggregators/Processors/Re-refiners, Burners and Crude Oil Refiners. The general flow of oil through the system and the number of players in each category are depicted in Figure 1.

Used motor oil generators (oil from an internal combustion engine crankcase) include every person who drives a car and either changes his or her own oil (a "do-it-yourself" (DIY) generator) or takes their car to a garage or oil-change service location (a "do-it-for-me" (DIFM) generator). Oil change services, also known as "quick-lube" or "fast lube" services are defined in the industry as businesses that derive the majority of their sales from quick, convenient oil changes.

Automotive quick-lube locations are responsible for significant volumes of used oil within the generator stakeholder group. DIFM quick-lube operations have expanded because of the convenience that they offer consumers both in terms of automobile maintenance and in avoiding the difficulties in disposing of their own used oil. As a result, the DIFM/DIY ratio has increased over the past 20 years to approximately 75 percent DIFM to 25 percent DIY for personal automobile oil changes.

The used oil generator category includes a wide range of companies that use equipment that relies on a variety of oils as elements of manufacturing or production process. These oils can include engine oils, compressor oils, electrical transformer oils, hydraulic oils, metal cutting oils or processing oils.

Figure 1. Used Oil Stakeholders
(Number of entities in each group shown in blue)



The used oil generated by these entities may be used onsite (e.g., in the case of used motor oil burned as space heater fuel at garages or DIFM locations), subsequently collected by companies in the collector category, or in the case of motor oil generated by DIYs, either taken to a central used oil collection location or disposed of in another manner. While the level of convenience for DIYs seeking to recycle their used oil varies from state-to-state and location-to-location within States, opportunities for DIYs to recycle their used oil have grown significantly since the 2006 report.

DIFM locations incur costs in accepting used oil from DIYs, which can be significant due to the risk of contamination of their used oil storage equipment by polychlorinated biphenyls (PCBs), a known animal carcinogen and a probable human carcinogen,[2] or other contaminants in volumes of DIY used oil. In fact, if the oil has been collected by an enterprise in the collector category and transported offsite, they may still remain liable for contamination found at that site,

[2] U.S. Environmental Protection Agency, "Learn about Polychlorinated Biphenyls (PCBs)," *available at* https://www.epa.gov/pcbs/learn-about-polychlorinated-biphenyls-pcbs#healtheffects.

depending on the applicable State and Federal regulations. Federal regulations regarding PCBs can also prove to create barriers to the safe and efficient collection, processing and re-refining of used oil by other stakeholders.

Used oil collectors act as intermediaries, transporting used oil between the generators and the aggregators/processors/re-refiners. They perform a vital service for the industry and their business is very competitive. Industry estimates indicate that there are 350-400 used oil collection companies in the United States. Since 2006, the collection sector of the used oil business has seen major consolidation.

When the value of used oil has fallen, collection companies have been able to maintain profit margins through more sophisticated, data-driven collection logistics as well as the trend toward larger parcel volumes at increasing numbers of DIFM quick-lube pick up locations. Used oil collection is influenced by crude oil price movements. When oil prices collapsed in 2015-2016 many collectors began charging for used oil pickup as used oil netback values for generators became negative. This led to some generators opting for alternative uses (space heater burning or improper disposal methods such as open burning or dumping). As a result of these factors, commercial used oil collection declined by at least 5 percent from pre-2015 levels. Nevertheless, used oil collections have remained fairly flat at about 900 MMG per year for the past decade.

Once collected, a variety of processes may be applied to transform used oil into usable products. Used oil re-refining is the term used to define processing that renders a primary final base stock product that can be used as the principal blending component in a lubricant. However, plants that subject the used oil to less severe processing (distillation) are employed to produce heavy distillates and the operators of these facilities are grouped into the sub-category of "used oil processors." There are a dozen or so of these companies currently operating in the United States. Thermal distillation or chemical treatment processes employed in these plants are designed to produce heavy distillates which are primarily channeled to crude oil refineries where they are converted in catalytic cracker or hydrocracking units to gasoline (more severe processing), diesel or other refined product, or used for direct blending into fuel oil. The vacuum gas oil/marine diesel oil (VGO/MDO) plants can often, with the addition of back-end hydro-treating, be converted to base oil production.

Total capacity within the used oil processor sub-category is about 332 MMG per year, of which about 254 MMG per year (77 percent) is currently operating. About 50 percent of the total domestic capacity has been added within the past 10 years. A few other used oil processors focus solely on specific used oil feedstocks like electrical transformer oils or industrial oils, regenerating those feedstocks for the market that produces them.

Companies within the used oil re-refining sub-category apply hydrotreating to collected used oil feedstocks to produce a base stock that can be used as a principal blending component in lubricants. The more intense processing facilities are more expensive to design and construct and more expensive to operate than simpler processing facilities. Today, there are 13 operating used oil refineries producing base stocks in the United States. The largest six together represent 89 percent of the Nation's installed capacity. The two largest re-refineries, both located in Indiana (East Chicago and Indianapolis) together account for about half of total U.S. capacity.

Today, the estimated volume of used oil feed being processed to produce base stocks in U.S. used oil refineries is 294 MMG per year. Used oil re-refineries have been running close to maximum effective capacity in recent years.

Collected used oil can be legally combusted as a fuel by businesses that are generators of used oil (e.g., quick lube services, commercial garages and service stations, vehicle fleet garages, etc.). These facilities may burn on-site generated used oil in space heaters to provide heat for their operations. While the 2006 report referenced 75,000 units nationwide, a current manufacturer estimates 100,000 such units are now operating nationwide, although sales have slowed since 2009. Used oil collectors also may sell unprocessed used oil directly to industrial end users (e.g., cement kilns, asphalt plants) for use in their plants as a lower cost alternative to fuel oil. Used oil burners are key end users of recycled oils and their decision-making is primarily dependent on the relative cost of alternative fuels; natural gas or fuel oil refined from virgin crude. The relatively low natural gas prices over the past decade have made used oil less competitive compared to natural gas on a British thermal unit (Btu) basis and have significantly reduced the demand for used oil in the industrial furnace and boiler markets where low priced gas is an option.

Another factor in the decision-making of generators with the option to burn a portion of collected used oil is the value offered (or charged) by the collector. If a used motor oil generator (e.g., a quick-lube service) is well paid for the used motor oil by a collector, the motivation to burn that used oil for space heating will be reduced. If they are instead charged per/gallon fees by the collector for pick-up of the used motor oil, the motivation to burn the oil for space heating will be greater. Collectors can get squeezed when wholesale prices offered fall for their used motor oil by processers and re-refiners, forcing them to charge for pick-up rather than pay for product. The data show that, since 2016, the motivation to burn used oil in space heaters may have increased, and that most often, collectors charged quick-lube services for pick-up in 2015-2016. However, recently more than half of DIFM operators are again being paid for their used oil.

The final stakeholder group in the used oil industry is the domestic crude oil refiners. The refiners are stakeholders in the sense that they produce the lubricants that will eventually become the used oil feedstock for the re-refining industry, as well as the lubricant base stocks and middle distillates that the processed used oil will compete with in the marketplace. Most importantly, the 13 operating used oil refineries compete directly on price and quality with 19 virgin (newly refined crude oil) base stock plants embedded in conventional domestic crude oil refineries.

In 2018, the volume of used oil unaccounted for at source (i.e., burned in space heaters by generators, recycled onsite or disposed of in some other manner, including DIY disposal in landfills or dumped into storm sewers, etc.) was estimated to be 429 MMG or about 31 percent of the used oil generated. This percentage is estimated to have remained fairly constant over the past decade, keeping in the 30-35 percent range. Based on data provided by the space heater industry, between 80 and 120 MMG of collected used oil is burned annually in space heaters by used oil generators. This amounts to between 18 and 28 percent of the estimated volume of used oil collected in 2018. Between 349 and 309 MMG per year of used oil remains unaccounted for, possibly lost to the environment. The accuracy of these estimates is problematic due to a lack of data, in particular with regard to estimates of loss in use, volumes of used oil collected, and volumes burned. It is clear that there is significant potential for improving the overall efficiency of used oil collection.

Life Cycle Analyses of Used Oil: Life cycle analysis (LCA) is used to evaluate whether re-refining used oil is more environmentally and energetically favorable than producing virgin oil from crude and whether any of the primary used oil dispositions (re-refining and combustion) is more environmentally and energetically favorable than the other. Since 2006, eight studies have been published on used oil dispositions. Four studies conducted by the Institute for Energy and Environmental Research (IFEU)[3] in 2018, API in 2017, CalRecycle[4] in 2013, and Safety-Kleen in 2014, were determined to be most reflective of current U.S. technologies and industry applications.

The studies developed by IFEU and Safety-Kleen compare the impacts of re-refining used oil against refining virgin oil from crude. These studies find the energy and environmental impacts for re-refining are nearly an order of magnitude less than the producing virgin oil. These LCAs assume used oil is a free waste and do not incorporate upstream impacts. API finds that when upstream impacts and product shortfalls are incorporated, used oil re-refining impacts are less favorable and potentially unfavorable compared to refining virgin oil from crude.

The LCAs developed by IFEU, CalRecycle, and API compare the energy and environmental impacts of used oil re-refining to used oil combustion. The IFEU study finds used oil re-refining more favorable than combustion across all impact categories, but that study models a combustion process that is used in the United Kingdom and is more resource intensive than combustion processes used in the United States. The CalRecycle and API studies find tradeoffs across the different used oil dispositions and conclude that increasing used oil collections will be overall more beneficial than any single disposition. Neither primary waste management strategy dominates the other in any of the major LCA impact categories, suggesting that each strategy has tradeoffs and benefits. Further, there are significant uncertainties in the underlying data and method differences in these LCAs, so that it is difficult to draw a decisive conclusion about the favorability of one used oil management strategy over another.

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[3] Institut für Energie und Umweltforschung Heidelberg (IFEU), translated to the Institute for Energy and Environmental Research, conducts research and provides a worldwide consultancy service in relation to all major environmental and sustainability issues.
[4] The California Department of Resources Recycling and Recovery, known as CalRecycle, is a department within the California Environmental Protection Agency.

Government Used Oil Programs Overview and Changes since 2006 Report

Federal Government Executive Orders Since 2006: Section 6002 of the Resource and Conservation Recovery Act (RCRA) includes statutory purchasing mandates requiring the re-use of waste products where possible. Subsequently, Executive Orders (EO) have been written by successive administrations to emphasize the implementation of these mandates with respect to used motor oil and recycled products.

EO 13101, “Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition,” enacted September 14, 1998, specifically required that “Agencies shall implement the U.S. Environmental Protection Agency (EPA) procurement guidelines for re-refined lube oils and retread tires.” EO 13149, “Greening the Government Through Federal Fleet and Transportation Efficiency,” enacted on April 21, 2000, specifically required that “no Federal agency shall purchase, sell, or arrange for the purchase of virgin petroleum motor vehicle lubricating oils when re-refined motor vehicle lubricating oils are reasonably available and meet the vehicle manufacturer's recommended performance standards.” Both of these EOs were revoked by EO 13423, “Strengthening Federal Environmental, Energy, and Transportation Management,” enacted January 26, 2007. EO 13423 was then subsequently revoked by EO 13693, “Planning for Federal Sustainability in the Next Decade,” enacted on March 19, 2015. Neither EO 13423 nor EO 13693 specifically mentioned re-refined motor vehicle lube oils or specifically directed Federal agencies to preferentially procure lubricants made from re-refined used oil. EO 13693 was subsequently revoked by EO 13834, “Efficient Federal Operations,” signed on May 17, 2018, and directs the head of each agency to meet the goals in the EO which are based on statutory requirements and specifically to implement waste prevention and recycling measures and comply with all Federal requirements with regard to solid, hazardous and toxic wastes. In addition, agencies are directed to acquire, use and dispose of products and services in accordance with statutory mandates for purchasing preference, Federal Acquisition Regulation requirements, and other applicable Federal procurement policies. Applicable statutory mandates include those established by RCRA Section 6002(c)(1), which requires Federal agencies to procure items containing recycled content that are designated by EPA. The EO 13834 Implementing Instructions specifically state agencies must give purchasing preference to products that meet minimum requirements for recycled content as identified by EPA in the Comprehensive Procurement Guidelines (CPG) which includes re-refined lubricating oil.

State and Local Government Activity Since 2006: The primary Federal regulation that applies to used oil was enacted by EPA and is established in Title 40 of the Code of Federal Regulations (CFR) part 279 (“Standards for the Management of Used Oil”). EPA’s management standards provided in 40 CFR part 279, essentially a set of "good housekeeping" requirements for used oil handlers, establish streamlined procedures for notification, testing, labeling, and record keeping, establish a flexible approach for tracking offsite shipments that allow used oil handlers to employ standard business practices, and set standards for the prevention and cleanup of releases to the environment during used oil storage and transit. All States were encouraged by the EPA to adopt the practices outlined in 40 CFR part 279 by developing Statewide programs for the management of used oils.

The 2006 report (which further established national used oil statistics) relied on a 1997 API study on used oil management based on a state-by-state survey. It showed that efforts to collect used motor oil were not uniformly distributed across the country. Over the subsequent decade, many States have made progress in supporting used oil collection and management. However, there are still areas of the country where used oil recycling remains less convenient than it could be.

Consistent with the previous report's suggestions, most states continued to execute 40 CFR part 279 practices with some additional modifications unique to their needs. Some States have instituted additional, State-level Government regulations similar to 40 CFR part 279. Many States have implemented proactive local programs for the collection of used oil, and a few provide funding to motivate progress at the county or municipal level.

Today, all 50 States and the District of Columbia have adopted regulations that pertain to the handling of used oils (collection, contamination, containers specifics, etc.). Thirty-six states have adopted the 40 CFR part 279 recommended management practices with some state-specific modifications, while 16 States have promulgated their own regulations, often quite similar to 40 CFR part 279. Accordingly, all 50 States and the District of Columbia have rules for handling of used oil and reporting on volumes of used oil collected.

Twenty-two States have enacted purchasing program preferences for recycled products of all kinds. Of these, six States specifically note lubricants derived from used oils as a preferred purchasing option (California, Hawaii, Missouri, Oklahoma, Pennsylvania, and Texas).

All 50 States have used oil collection locations operated by state or local entities. Only five States operate collection centers funded directly by the state (California, Delaware, Illinois, Indiana, and Maryland). In all other States and the District of Columbia the collection centers are operated under county or local (town, township, city, etc.) auspices. Some States provide grants for local organizations to operate collection centers. All 50 States and the District of Columbia require retailer collection of used oil.

Thirty States have online searchable databases (or in some cases printable lists) of collection center and retailer locations where used oil can be recycled. The other States generally direct individuals interested in recycling used oil to call their city or country office. An independent website has developed a database of used oil recycling collection locations (retailer, city, county and State locations) searchable by zip code.

Many local communities, cities, towns, townships, and counties, fund and manage used oil collection centers as stand-alone drop off points or as one of several recycling options within a larger recycling location. Some local jurisdictions also hold intermittent collection events where DIYs can bring used oil to a publicized location for collection. Some communities also offer "curbside" collection programs that allow consumers to put their oil out on the curb for collection, as they already do with their other recycling and trash.

Public used motor oil recycling location data indicates that there are areas of the country were taking advantage of the opportunities for recycling may be more difficult and opportunities for enhanced services or improved outreach could lead to higher collection rates.

Stakeholder Perspectives

A number of industry stakeholder representatives participated in the U.S. Department of Energy's (DOE) data gathering efforts for the 2006 report update. These individuals and organizations provided a wealth of data and perspectives that have provided critical inputs into the revised and updated report. Several of the contributor perspectives are summarized here.

The Used Oil Refining Coalition (UORC)[5] vision is one that is benefited and shaped by close focus on the used oil molecule. As the quality of the used oil molecule has improved steadily, the used motor oil pool is populated with ever-higher quality lubricants. UORC believes valuing the used oil molecule based solely on its heating content (i.e., burning) is an increasingly out-of-date approach to what could otherwise be a strategic advantage in better resource management, energy independence, and energy dominance. As the used lubricant molecule is valued according to its increasingly higher quality as a feedstock, and not simply for its heating content, UORC believes that a hierarchy of disposition routes is more important today than when it was embraced in the previous decade. UORC does not intend for a hierarchy to limit or discourage other legal dispositions, but rather to serve as a framework within which the used oil refining industry can collaborate on a defined strategy that benefits stakeholders across the value chain. UORC believes used lubricant refining should be viewed as a strategic provider of petroleum products rather than a simple waste repository.

The National Oil Recyclers Association (NORA)[6] encourages increased responsible collection of used oil, promotion of sustainable reuse of used oil by Federal agencies, and dissemination of public information concerning sustainable reuse options for used oil. NORA recommends the Federal Government collect or facilitate an effort to accurately quantify used oil generated and collected on a recurring basis. NORA also addresses concerns about PCB issues, which because

[5] The UORC is a non-profit coalition of four of the world's leading used oil collectors, used oil refiners, and suppliers of regenerated lubricants to consumers, primarily in North America. The UORC's constituent members are Safety-Kleen, Inc. (a division of Clean Harbors); Heritage-Crystal Clean, LLC; Avista Oil; and Vertex Energy, Inc. In aggregate, 92 percent of the U.S. and one-third of the world's collected volumes of used oil that are refined into base stocks are processed by the UORC members.

[6] NORA is a trade association that represents more than 325 companies in the liquid recycling industry. It was established in 1985 as the National Oil Recyclers Association and the name was later changed to NORA, An Association of Responsible Recyclers. NORA represents the leading liquid recycling companies in the areas of used oil, antifreeze, oil filters and absorbents, parts cleaning, wastewater and chemicals.

of potential environmental liability may impede responsible economic recovery, recycle, and re-refining of used oil. NORA encourages EPA to re-consider their stance on PCB contamination in a manner that encourages used oil collection. In order to promote sustainable reuse of used oil, NORA recommends the Federal Government coordinate with various stakeholders for common messaging, and identify current efforts related to used oil and evaluate what can be enhanced. Additionally, NORA advises that without more enforcement, economic incentives to properly manage used oil generated may decline at the generator level and more charge-for-my-oil may lead to non-permitted and illegal disposal activity.

The API,[7] representing crude oil refiners and used oil refiners along with lubricant marketers, indicated that uncertainty surrounding the amount and accuracy of comprehensive used oil data has impeded overall improvements in used oil management. Additionally, API has concluded in a recent lifecycle cost assessment that impacts of uncollected used oil are significant but that no single disposition yields the lowest environmental/energy impact under all conditions. API advises that any disposition preference encouraged by Government policy should not jeopardize collection rates and that a periodic survey of used oil use volumes and a review of worldwide used oil programs should be conducted to identify and foster used oil collection. API's perspective is that a Federal strategy should focus on identifying market-enhancing mechanisms and protocols to measure and increase the collection of used oil. Additionally, API advises a Federal strategy should allow the marketplace to develop and maintain a broad portfolio of used oil dispositions related to both lubricant petroleum products and fuel petroleum products, and any strategy should not institute market-distorting biases that favor any single used oil disposition route.

Further, API encourages the development of cost-effective technology for identifying PCB contamination in used oil and progress towards a more equitable approach to assigning liability for the introduction of PCB-contaminated used oils amongst the parties involved in the generation, collection, and disposition of used oils. Finally, API strongly encourages the formation of an advisory group of used oil stakeholders to provide input to the Federal Government on identified issues concerning strategies to promote the beneficial utilization of used oil within the broader petroleum products marketplace.

The perspective of Rock Energy Systems, LLC (RES), a parent company of three leading brands of space heating products, is that it is economically advantageous for some used oil generators to legally and safely combust a portion of the oil they collect in space heaters for energy recovery. The economic benefit of this choice can outweigh the benefit they derive from having that used oil collected and paying for another heating fuel. It is RES' position that oil generators' ability to heat their facilities with used oil continues to provide significant economic benefit to many small businesses and supports the value proposition for used oil in the U.S. economy.

[7] API is the only national trade association representing all facets of the natural gas and oil industry with more than 600 members, including large integrated companies, as well as exploration and production, refining, marketing, pipeline, and marine businesses, and service and supply firms. API promotes recycling and provides information on used oil recycling and a link to *Earth911* at its website for locating recycling centers in the United States.

The Automotive Oil Change Association (AOCA) represents thousands of automotive maintenance centers throughout North America. AOCA supports the NORA's proposed solution for PCB-contaminated DIY used oil, recognizing the difference between unintentional and intentional dilution, and eliminating and/or reducing notices of violation. Penalizing responsible management of PCB-contaminated DIY used oil does nothing to protect the environment but bleeds the resources necessary to do so. AOCA also supports incentives for re-refining and other forms of recycling of on-spec used oil. Further, AOCA supports enhanced voluntary compliance auditing for recyclers so that the generator and transporter community can identify the most responsible used oil recyclers, reducing their risks of being held liable for downstream pollution resulting from used oil collected from their locations.

The perspectives of a specific subset of the used oil recycling business, transformer oil re-refiners, is provided by Hydrodec of North America, LLC. Hydrodec collects used transformer oil in-the-field from transformers that have reached the end of their 20-30 year working life or become damaged as a result of weather. The company's clients are typically utilities and Government entities. Hydrodec believes that re-refining of transformer oil should be mandatory in the United States or at the very least encouraged as a "best practice," as it keeps the oil in use for an indefinite period and it from being discarded, causing pollution and exposing utilities to possible litigation. Hydrodec believes that transformer oil should be included along with lubricating oil in any DOE efforts to enhance collection efforts.

Recommended Actions to Improve Collections and Increase Beneficial Reuse of Used Oils

The data gathering and analysis carried out to prepare this report revealed a number of opportunities for relevant Federal agencies to take action, independently or in coordination with other agencies or groups, to help to ensure the societal benefits of increased used oil collection and recycling and a well-functioning used oil marketplace. These actions are defined in greater detail in Section XII of the report and are summarized in Table 1.

Table 1. Opportunities and Recommendations for Actions

Category	Actions
Information Exchange and Outreach	• Establish a Stakeholder Advisory Group for the purpose of gathering additional information and addressing unresolved issues. • Update and enhance website information on used oil. • Investigate ways to inform do-it-yourself oil changers of the locations of used motor oil recycling locations via a centralized website. • Investigate ways that Federal action might be used to increase used oil collections in States and identify ways to improve public awareness.

Category	Actions
Data Collection and Research	• Implement research and data collection activities to better quantify used oil statistics. • Carry out a scoping study to investigate the potential benefit of a National Laboratory research effort to develop a test kit for PCBs. • Work with State regulators to collect and compile State level data on used oil collection and disposition; survey State regulators and develop a comprehensive set of "best practices" for enhancing collection. • Collect information on and evaluate foreign used oil collection programs and identify "best practices" and insights for U.S. policies.
Data Analysis	• Utilizing National Laboratory resources, carry out a comprehensive life cycle analysis that quantifies the relative energy and environmental costs of re-refining used oil to produce lubricants, burning used oil, and re-refining or processing used oil to non-lubricant products. • Using data collected (see above section) carry out analyses of used oil recycling programs and current used oil dispositions to determine where efforts to increase collections should be focused. • Encourage States that offer State tax incentives to small businesses that buy space heaters to confirm whether those programs are aligned with State priorities. • Work with the Department of Commerce to evaluate the economic and security risks, if any, of a sudden cut off in Group III lubricant imports.
Policy Development	• Evaluate the potential economic benefits of implementing a policy that would eliminate or reduce notices of violation and allow industry to manage used oil in "as-found" condition, including a more equitable approach to assigning liability for the introduction of PCB-contaminated used oils. • Review current government purchasing preferences for bio-based lubricants and lubricants re-refined from used oil to identify opportunities to disseminate information on the established preference regarding use of recycled oil and bio-based lubricants and increase awareness. • Conduct analysis to evaluate whether the inclusion of bio-based lubricants in the used oil collection stream contaminates the feedstock or negatively impacts the re-refining process. Undertake a study of technical complications in the re-refining of used oils from lubricants containing notable levels of select bio-based or ester base stocks and their implications should be completed. • Evaluate the costs and benefits of tax incentives that encourage the re-refining of used motor oil. • Consider options for providing grant funding or other incentives for use of oils refined from used motor oils.

Category	Actions
	• Consider Federal options for supporting enhanced voluntary compliance auditing for used oil processors and re-refiners.

The recommendations of this report, as outlined above, must be placed within a strategic framework for implementation. The legislation directing this update of the 2006 report requires that DOE prepare and submit to Congress "a coordinated Federal strategy to increase the beneficial reuse of used lubricating oil" that:

- Is consistent with national policy (Used Oil Recycling Act of 1980 - Public Law 96–463);
- Addresses measures needed to increase the responsible collection of used oil and disseminate public information concerning sustainable reuse options for used oil; and
- Promotes sustainable reuse of used oil by Federal agencies, recipients of Federal grant funds, entities contracting with the Federal Government, and the general public.

The strategy for implementing these recommended actions is provided as a separate document (Attachment 1 to this report), titled *Federal Strategy on Used Oil Management and Beneficial Reuse Options to Address Section 1. Energy Savings from Lubricating Oil, Public Law 115-345*.

III. Lubricants and Current Trend

Used Oil Basics

Lubricants are used to reduce friction between bearing surfaces, are incorporated into other materials to use as processing aids in the manufacture of other products, or are used as carriers of other materials. All lubricants start with a base oil. Typically, the ratio is somewhere around 90 percent base oil, plus 10 percent additives. Petroleum lubricants may be produced either from distillates or residues. Lubricants include all grades of lubricating oils—from spindle oil, to cylinder oil, to those used in greases. Used oil is defined as any oil that has been refined from crude oil or any synthetic oil that has been used and, as a result of such use, is contaminated by physical or chemical impurities. In other words, it is any petroleum-based or synthetic oil that has been used as a lubricant or for any other industrial purpose. During normal use, impurities such as dirt, metal scrapings, water, or chemicals can get mixed in with the oil and, over time, the oil no longer performs well as a lubricant. Eventually, this used oil must be replaced with virgin or re-refined oil. There are three types of base oils: (1) mineral, (2) vegetable, and (3) synthetic. Mineral oil comes from crude oil, and the quality depends on the refining process. Lubes made from vegetable oils are called bio-lubricants. Synthetic oils are man-made fluids and can be beneficial for use in extreme conditions. Additives are used to impart specific characteristics to any given oil-based lubricant, and the additives vary across the differing types and uses of lubricants. Common types of additives include antioxidants, detergents, anti-wear, rust/corrosion inhibitors, extreme pressure, anti-foaming agents, and viscosity index improvers.[8]

The used oil can be: (1) reconditioned on site, i.e., impurities are removed from the used oil, which is then reused to prolong its life; (2) sent to a petroleum refinery and introduced as a feedstock into refinery production processes; (3) re-refined, which involves treating used oil to remove impurities so that it can be used as a base stock for new lubricating oil (re-refining extends the life of the oil resource indefinitely); and (4) processed and burned as fuel to generate heat or to power industrial operations. The latter is not as preferable (from a recycling perspective) as other options because it only allows for one reuse of the oil.[9] Improper handling and burning of used oil raises environmental and health concerns due to uncontrolled release of hazardous emissions. Per the EPA, re-refining used oil is the preferred form of recycling because it closes the recycling loop by reusing the oil to make the same product that it was when it started out, using less energy and less virgin oil.[10] The key considerations for the reuse hierarchy include market needs, economic value, environmental benefit, energy value, infinite reuse, and upcycling.

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[8] Petroleum Service Company, *Understanding Types of Lubricants: Base Oil Groups* (January 18, 2017), *available at* https://petroleumservicecompany.com/blog/understanding-types-of-lubricants-base-oil-groups/.
[9] U.S. Environmental Protection Agency, "Managing Used Oil: Answers to Frequent Questions for Businesses (April 29, 2019)," *available at* https://www.epa.gov/hw/managing-used-oil-answers-frequent-questions-businesses.
[10] *Id*.

Virgin Oil to Used Oil

As an oil application reaches the end of its useful life and its physical properties are altered, the oil still provides many beneficial reuse options—primarily re-refinement into oils and fuels or burning for energy content. Technology advancements, along with a continued increase in the quality of lubricants, provide opportunities to process used oil into fuels, re-refine into low-sulfur/high-value middle distillates or base stocks. The waste management hierarchy detailed in Table 2 is expressed in the waste management policy sections of RCRA and Pollution Prevention Act. The "Considered Action Step" is the logical application of the used oil hierarchy, starting with the most preferred environmental option, ending with the least preferred environmental option. Additional discussion on used oil disposition is provided in Section X.

While there is no accurate accounting of the amount of used oil, based on industry estimates, used oil collection in the United States has been in the range of 900 million to 1 billion gallons/year; and, in 2017, used oil refining accounted for about 50 percent of the collection.[11] The U.S. lubricant consumption has remained essentially flat in the past decade. According to the EPA, about 200 MMG of used oil are improperly disposed each year.[12] Used oil can pollute the environment if it is not recycled or disposed of properly by local waste management authorities or automotive repair shops. Used oil filters pose similar waste concerns; and, if properly drained, can also be safely recycled or disposed of.

Table 2. Resource Conservation Hierarchy

Waste Management Ranking (from Environmental Perspective)	Option	Considered Action Step
Most Preferable	Prevent the waste in the first place	Source reduction (e.g., extended oil drain intervals)
↑	Re-use and reclaim the product	Re-refine used oil
↑	Recover energy by burning	Combust used oil for heating value recovery *
Least Preferable	Dispose of the waste by land filling or incineration	Recover and collect used oil for proper disposal

* The environmental ranking of combusting used oil depends on the fuel that is displaced. Displacement of high environmental impact fuels like coal or petroleum coke would make combustion of used oil rank higher from an environmental perspective.

Base Stocks

As automotive and industrial technologies continue to evolve, demand for higher-performing lubricants has grown. Lubricants and industrial oils, part of the broad range of petroleum-derived products that make modern life possible, fill critical roles in a wide array of applications.

[11] Kline & Company.
[12] U.S. Environmental Protection Agency, Basic Information: Common Wastes and Materials (Feb. 21, 2016), *available at* https://archive.epa.gov/wastes/conserve/materials/usedoil/web/html/oil.html.

Additionally, modern lubricants can directly contribute to the improved environmental performance of operating mechanical systems. Once lubricants become used oil, various reuse options—including regeneration or re-refining, processing to fuels, or direct use as fuel—are viable alternatives to disposal.[13] One important end product of used oil re-refining is high-quality lubricant base stocks that can be used to create new lubricants. The American Petroleum Institute classifies five base stock groups, Groups I, II, III, IV, and V, which are determined by the amounts of saturated compounds and sulfur in the oil and its viscosity (shown in Table 3). There are also Group II+ and Group III+ base stocks. Group II+ offers higher viscosity index than many Group II base stocks (112–119), and Group III+ does the same for Group III base stocks with a viscosity index of 130 or greater. Generally, Group III base stocks have lower levels of impurities and aromatics content than Group II base stocks. Additional information on lubricants is provided in Appendix A – Lubricants Primer.

Table 3. API Base Stock Classification

API Group	Saturates (Percent Weight)	Sulfur (Percent Weight)	Viscosity Index
I	<90 and/or	>0.03 and	80-119
II	≥90 and	≤0.03 and	80-119
III	≥90 and	≤0.03 and	≥120
IV	Polyalphaolefins (PAO)		
V	All other base stocks not included in Groups I, II, III or IV		

Groups I, II, III are mineral-based and refined from crude oil. Groups IV and V are synthetic base stock oils. Synthetic oils have a much broader temperature range and are appropriate for use in extreme cold conditions and high heat applications.[14]

Global Lube Oil Market

Worldwide, an estimated 3.8 billion gallons of used oil was collected commercially in 2017, of which 27 percent was directed to used oil refineries to produce base oils. Global demand for lubricants has increased 15 percent per year since 2001, which was 10.8 billion gallons. The current status of total lubricant demand by global region is shown in Table 4 and Figure 2. The United States is responsible for 21 percent of total worldwide demand; at 7.6 gallons per year, its per capita lubricant demand is more than double the next closest region. As the largest overall consumer, the Asia-Pacific region consumes nearly 43 percent of total worldwide demand, at approximately 5.1 billion gallons per year, but its per capita lubricant demand (1.5 gallons per year) is due to the large populations of China and India. From Table 4, it is evident that European per capita demand trails only the United States. The U.S. lubricant demand has been relatively stable, around 2.5 billion gallons since 2014, with approximately half of all products

[13] Adapted from "Used Oil, Reducing Environmental Impacts of the System as a Whole" API Presentation to DOE, September 4, 2019.
[14] Machinery Lubrication, Base Oil Groups (October 2012), *available at* https://www.machinerylubrication.com/Read/29113/base-oil-groups.

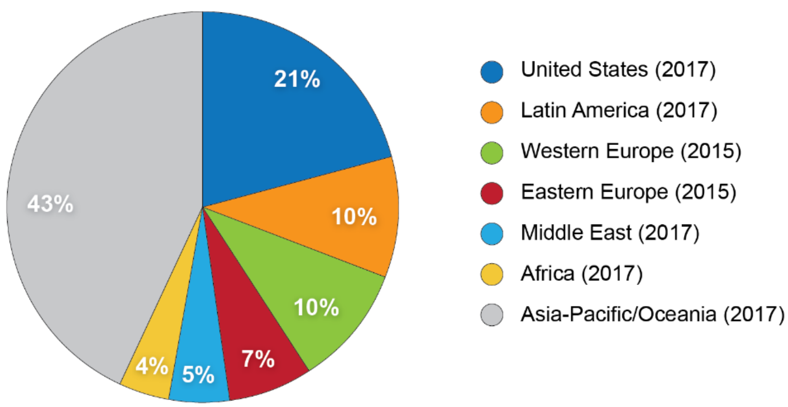
consumed within the automotive segment and the other half consumed within industrial applications.[15]

Table 4. Total Lubricants Demand by Region [16]

Region (Year)	Demand, Billion (Gallons/Year)	Per Capita Demand (Gallons/Year)
Asia-Pacific (2017)	5.1	1.5
United States (2017)	2.5	7.6
Western Europe (2015)	1.2	3.3
Latin America (2017)	1.1	1.7
Eastern Europe (2015)	0.8	3.5
Middle East (2017)	0.6	1.4
Africa (2017)	0.5	0.4
Total (2015; 2017)	**11.8**	**1.8**

Per capita data based on respective year statistics.

Figure 2. Global Lubricant Demand [17]



Longer drain intervals between oil changes for late model vehicles and increased use of electric vehicles have impacted demand growth in developed markets. Electric vehicles typically require less maintenance than conventional vehicles because there are usually fewer fluids to change and far fewer moving parts than gasoline- and diesel-fueled vehicles. However, increased industrialization and motorization are keeping demand growth in the Asia-Pacific region ahead of other regions.[18] The much higher per capita use of the automobile in the United States

[15] "Lubes'N'Greases 2019-2020 Factbook," The U.S. Marketplace, August 2019.

[16] "Indicative Used Oil Balances of Selected Countries Around the World," Kline Lubesnet Database, Kline & Company, 2019.

[17] Based on data from Kline & Company.

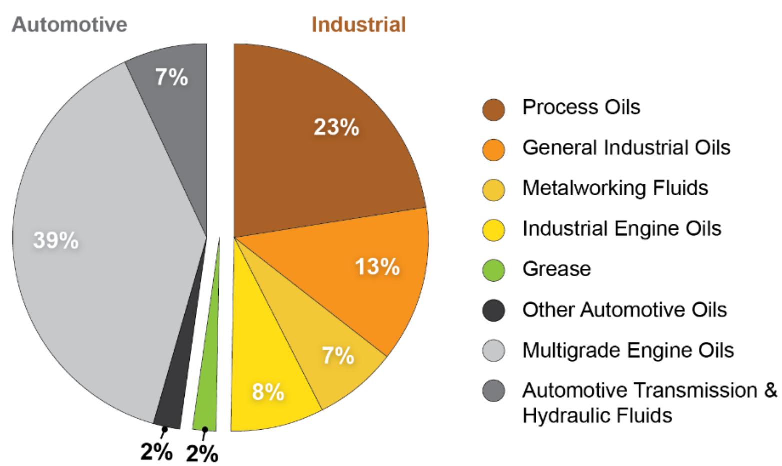
[18] Lubes'N'Greases 2019-2020 Factbook, Global Lubricant Perspectives, August 2019.

compared to other regions contributes to the high per capita lubricant demand. Western Europe also has a high level of industrial activity, but this region is much less dependent on personal automobiles due to a more established mass transit infrastructure. The relative importance of automobile lubricants in the United States is shown in Table 5[19] and Figure 3.[20]

Table 5. U.S. Lube Oil Demand by Type (2018)

Lubricant Type	Demand, Billion (Gallons/Year)	Percentage of Total Demand (Percent)	Typical Applications
Industrial Oils	1.26	50	Process oils, general industrial oils, metalworking fluids, industrial engine oils
Automotive Fluids	1.21	48	Automotive transmission and hydraulic fluids, multi-grade engine oils, other automotive oils
Grease	0.05	2	Automotive and industrial
Total	**2.52**	**100**	

Figure 3. U.S. Lubricant Sales by Product (2018) [21]
(Total: 2.5 billion gallons)

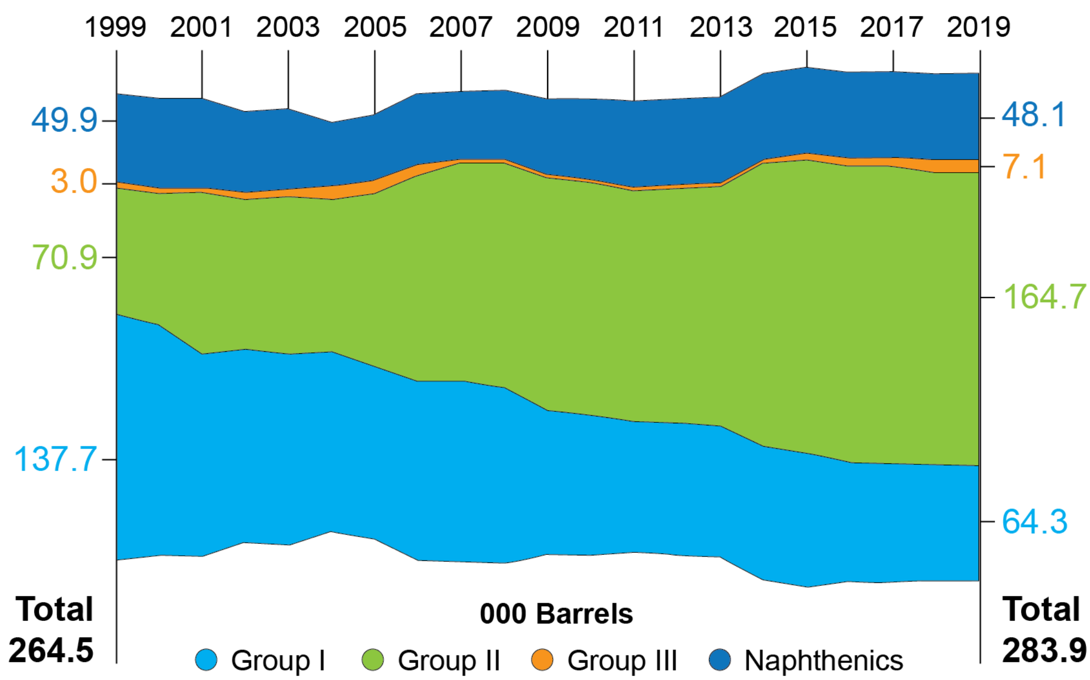


[19] Adapted from "Lubes'N'Greases 2019-2020 Factbook," 2018 Lubricant Sales by Product, August 2019.
[20] *Ibid.*
[21] Kline & Company.

Recent Trends in Use of Higher Quality Base Stocks and Motor Oil Grades, and Implications on Used Oil Management

Despite a drop in the number of production facilities, North American production capacity of crude oil refined to virgin oil (refined from crude oil) is up by 19,000 barrels per day compared to 30 years ago, and Virgin API Group II and Group III continue to outpace Group I production (shown in Figure 4).[22] North American production capacity for Group III lubricants remains relatively small.

Figure 4. North American Base Stock Capacity Shifts
(includes U.S., Canada, Mexico)



264,500 barrels = 11,109,000 gallons
283,900 barrels = 11,923,800 gallons

The 2018 U.S. production of Group III and Group III+ base stocks of 3,900 barrels per day accounts for only 2 percent of total U.S. base stock production.[23] More than 80 percent of U.S. imports of Group III and Group III+ base stocks come from South Korea, Indonesia, and the Middle East.[24] Re-refiners are making significant capital investments to enable used motor oil refineries to produce Group III base stock in anticipation of growing U.S. demand. The manufacturing technology and process are identical between most of Group II and Group III base

[22] "Lubes'N'Greases 2019-2020 Factbook," Base Oils in North America, August 2019.
[23] "U.S. Base Oil Capacity and Production in 2017 and 2018" Kline Lubesnet Database, Kline & Company, 2019.
[24] Kline & Company data provided by UORC.

stocks. When economics are favorable, some Group II producers in the United States can transition their product stream to Group III quality. The economics of making Group III relative to Group II will be determined by the supply-demand dynamics of these products in the marketplace. Imported Group III base stock meets a portion of the formulation need for low viscosity engine oils, as well as certain industrial lubricants and greases. Domestic production of higher quality Group II+ base oils and Group III base oils has the potential to reduce the dependence on imported Group III in the future. The ongoing trend of engine oils moving into lower viscosity (0W, 5W and 10W grades) will likely lead to increased demand of higher quality base stocks. However, a large portion of such demand could be met with domestic supply in North America, as more base stock producers begin to upgrade their base stock quality into Group II+ range. The ongoing base stock quality upgrade in the United States has the potential to displace a large portion of Group III demand.[25]

As pressure has increased for higher fuel economy and lower emission levels, recommended vehicle oil change intervals for newer passenger vehicles has grown from 3,000 miles to more than 10,000 miles, which had a significant impact on lube oil demand. As oil quality has improved and is re-refined, the volumes of higher quality used motor oil continue to rise, and its use as a feedstock for re-refinement becomes a more economically appealing option. Re-refined oils leverage the same refining process as the production of virgin base stocks from crude oil. The higher quality of the initial state of the used oil enables better end products from the re-refining process. In addition to the impact of government fuel efficiency standards on new automobile lubricant demand, additional performance requirements will have an increasing impact on the markets for used oil products. For example, see Section IX for more details on marine fuel oil demand.

Impact of Shale Oil and Shale Gas

Recent increases in U.S. natural gas and oil production have largely come from unconventional shale and tight oil reservoirs, which have become more accessible and economic due to advancements in horizontal drilling and hydraulic fracturing techniques.[26] The largest tight oil plays in terms of production are the Eagle Ford (Texas), Bakken (Montana and North Dakota), and Permian (West Texas).[27] All these tight oil plays (group of oil fields) also produce substantial amounts of associated gas during oil production. Shale gas is produced from a number of plays, the largest of which is the Marcellus Shale, primarily in Pennsylvania and West Virginia.

Of total U.S. natural gas production, the natural gas production from shale gas and tight oil plays continues to grow in both share and absolute volume. The sheer size of the associated resources

[25] API response to DOE questions, October 11, 2019.
[26] The Brattle Group for American Petroleum Institute, "Understanding Crude Oil and Product Markets" (2014), *available at* https://www.api.org/~/media/Files/Oil-and-Natural-Gas/Crude-Oil-Product-Markets/Crude-Oil-Primer/Understanding-Crude-Oil-and-Product-Markets-Primer-High.pdf.
[27] *Id.*

and improvements in technology allow for the development of these resources at lower costs.[28] In 2018, natural gas production from shale gas wells [23.55 trillion cubic feet (Tcf)] accounted for 63 percent of total U.S. natural gas production (37.1 Tcf).[29] In 2007, natural gas production from shale gas wells was approximately 2 Tcf.[30]

In 2018, U.S. tight oil production reached 6.5 million barrels per day, accounting for 61 percent of total U.S. production. Projections indicate tight oil production growth as the industry continues to improve drilling efficiencies and reduce costs, which makes developing tight oil resources less sensitive to oil prices than in the past.[31] The U.S. Energy Information Administration's (EIA) Annual Energy Outlook 2019 (AEO2019) Reference Case projects that U.S. tight oil production, which became the more common form of oil production in 2015, will continue to increase through 2030—ultimately reaching more than 10 million barrels per day in the early 2030s.

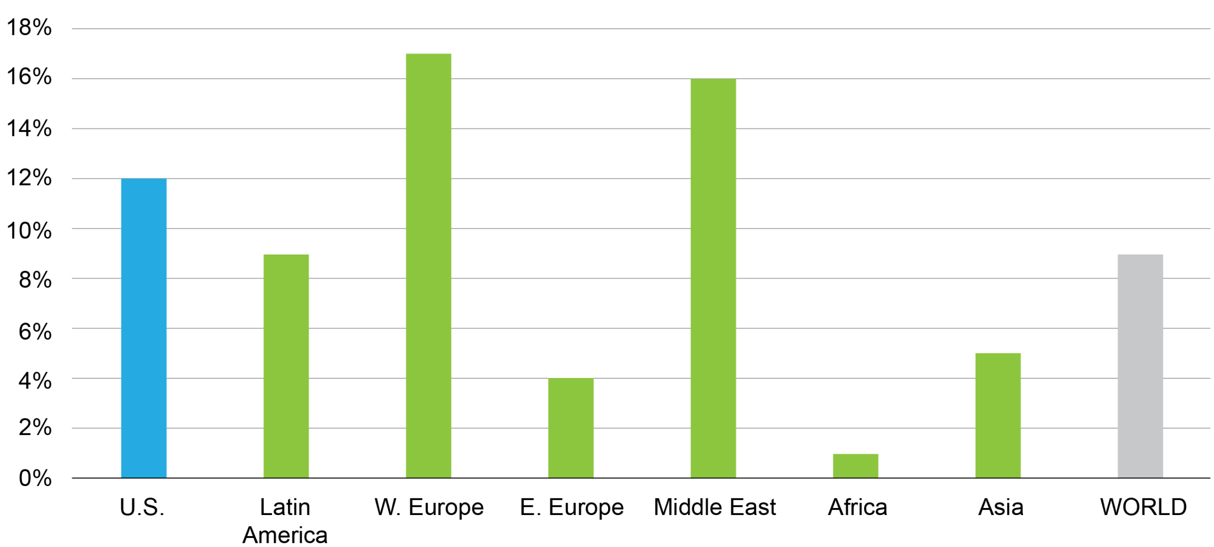
Tight oil production tends to have larger amounts of associated gas than most conventional crude oils. The large amounts of associated gas are often more volatile and, in some instances, trend into the condensate range. As a result, tight oil production results in larger amounts of associated gas produced along with crude oil. Associated gas production will continue to exert downward pressure on domestic natural gas prices, making natural gas a more competitive, economically attractive fuel option than fuel oil refined from used oil for use as a fuel for boilers, processing plants, and heaters. The increased production of associated gas from tight oil plays that are being rapidly developed for their oil, has added to the overall supply of natural gas and lowered its price. In 2006, the average natural gas price was $6.75 per thousand cubic feet (Mcf), as compared with $2.59 per Mcf average price in 2019 through November.[32] This low-priced natural gas has replaced demand for used oil as a fuel in industrial applications, such as asphalt plants and cement kilns.

[28] U.S. Energy Information Administration, Annual Energy Outlook 2019 at 76, (January 2019).
[29] U.S. Energy Information Administration, Natural Gas Gross Withdrawals and Production (Jan. 31, 2020), *available at* https://www.eia.gov/dnav/ng/NG_PROD_SUM_DC_NUS_MMCF_A.htm.
[30] U.S. Energy Information Administration, U.S. Natural Gas Gross Withdrawals from Shale Gas, *available at* https://www.eia.gov/dnav/ng/hist/ngm_epg0_fgs_nus_mmcfm.htm.
[31] U.S. Energy Information Administration, "Tight oil development will continue to drive future U.S. crude oil production," March 28, 2019, *available at* https://www.eia.gov/todayinenergy/detail.php?id=38852
[32] U.S. Energy Information Administration, U.S. Natural Gas Gross Withdrawals from Shale Gas (Jan. 31, 2020), *available at* https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm.

IV. Worldwide Used Oil Management Practices

Worldwide, an estimated 3.8 billion gallons of used oil was collected commercially in 2017, of which, 27 percent was directed to used oil refineries to produce base stocks.[33] There are wide differences in the management of used oil around the world. Outside of North America, Western Europe, and the Middle East, most of the used oil is still burned. Proportions of collected used oil channeled to base stock refining vary significantly around the world, and more than 50 percent of collected used oil is burned, excluding uncollected used oil burned at the source. In 2017, the United States re-refined approximately 12 percent, or 287 MMG of lubricants consumed to base stocks. In the same year, the Asia-Pacific region re-refined an estimated 5 percent, or 255 MMG; Latin America re-refined an estimated 9 percent, or 99 MMG; the Middle East re-refined an estimated 16 percent, or 96 MMG; and Africa refined an estimated 1 percent, or 5 MMG. In 2015, Western Europe re-refined an estimated 17 percent, or 204 MMG, and Eastern Europe re-refined an estimated 4 percent, or 32 MMG. Re-refined base stocks as a percentage of lubrication consumption across global regions is shown in Figure 5.

Figure 5. Re-Refined Base Stocks as a Percentage of Lubricant Consumption



* Data were developed for various years by country, but are generally representative of the 2015-2018 time frame

Sources: GEIR, Kline Estimates

The United States ranks tenth among major economies in terms of percentage of collected used oil re-refined to base stocks, but highest for total volume of used oil collected.[34] Countries with incentives for used oil refining have higher proportions of recycling used oil to base stocks. While incentives designed to improve the recovery or reprocessing of used oil exist in several advanced economies, the systems applied to meet these goals differ widely. Domestically, the State of California provides a recycling incentive payment to Certified Collection Centers and curbside collection operators. Subsidies paid for used oil recycling are most commonly funded

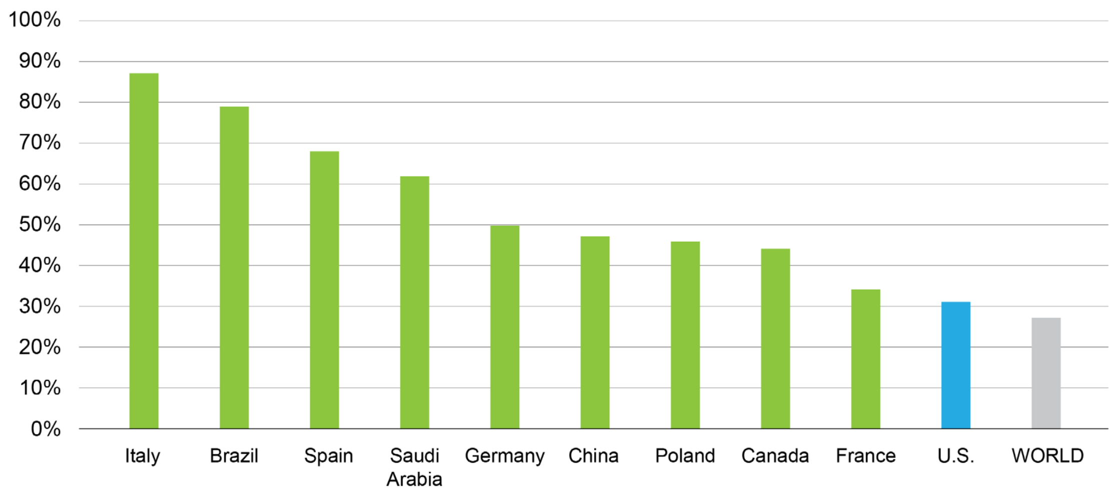
[33] Information provided by the Used Oil Refining Coalition.

[34] *Ibid.*

by taxes on finished lubricants sales. There are no common models of how governments or industry associations in place of governments establish used oil refining and collection incentives.

Some governments offer subsidies for both collection and refining, such as in Italy and Spain, and some governments subsidize only refining but not collection, such as in Australia. Other governments focus on incentives for collection only, such as in certain Canadian provinces and Portugal, while other governments use tax waivers, such as China, while Brazil bans all used oil burning. Germany introduced used oil refining incentives in 2002, but they were abolished in 2007 when domestic resource recovery facility (RRF) capacity had more than doubled in response to subsidies.[35] Italian RRF subsidies are indexed to changes in world oil prices, and Australia plans to reduce the current incentive payments for recycling to base stocks when regeneration goals are met. Re-refined used oil as a percentage of used oil collected is illustrated in Figure 6.

Figure 6. Re-Refined Base Stocks as a Percentage of Used Oil Collected



* Data were developed for various years by country, but are generally representative of the 2015-2018 time frame
Sources: GEIR, Kline Estimates

Although the United States represents the highest per-capita lube oil consumption in the world, the focus on re-refining used oil is less than in most other industrialized countries. With a re-refining rate of approximately 12 percent of lubricants consumed (see Figure 5), and a consumption of approximately 2.5 billion gallons (see Table 5), the United States refined an estimated 287 MMG in 2017. This reflects approximately 31 percent of used oil collected in the United States, as shown in Figure 6. The major countries in Europe, on the other hand, have active programs designed to increase the recovery of lube oils, and some promote re-refining as the ultimate step in recycling. Waste disposal from member states of the European Union (EU)

[35] Information provided by the Used Oil Refining Coalition.

are bound by the Waste Framework Directive (WFD) (2008/98/EU).[36] Additionally, EU member states may prescribe that waste oils shall be regenerated if technically feasible and may restrict the transboundary shipment of waste oils from their territory to incineration or co-incineration facilities to give priority to the regeneration of waste oils.[37]

In 2016, about 13 percent of all base stocks consumed in the EU and approximately 12 percent of all base stocks consumed in the United States come from re-refined waste oils. The remaining virgin base stocks are produced from crude oil refining, mostly imported,[38] and produced by major global players.[39] 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.[40]

Observations on Worldwide Used Oil Programs

Used oil management practices vary considerably between nations and global regions; however, globally, the collection and refinement of used oil is increasing due to quality improvements of re-refined base stocks, fluctuating crude oil prices, reduced energy cost to reprocess used oil than refinement of crude, and stringent environmental standards.[41]

Used Oil Programs in the United States

At a national level, the U.S. Comprehensive Procurement Guideline (CPG) program is part of EPA's Sustainable Materials Management initiative that promotes a system approach to reducing the use of materials and their associated environmental impacts throughout their life cycles. The CPG program is authorized by Congress under Section 6002 of RCRA.[42] CPG continues the effort to promote the use of materials recovered from the municipal solid waste stream, and buying products made with recovered materials ensures that the materials collected in recycling programs will be used again in the manufacture of new products. RCRA section 6002(i) requires Federal agencies purchasing more than $10,000 of an item listed on the CPG, or functionally

[36] European Commission, Waste Framework Directive 2008/98/EC, *available at* https://ec.europa.eu/environment/waste/framework/.
[37] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, Article 21 Waste Oils, Official Journal of the European Union. November 22, 2008, *available at* https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN.
[38] Currently, about 13 percent of all base oils consumed in the EU come from re-refined waste oils. The other 87 percent are virgin base oils produced from crude oil refining, mostly imported and produced by major global players. Western Europe relies heavily on base oils imports and meets approximately 17 percent of local demand (used oil re-refined to base oils as a percentage of lube consumed).
[39] Groupement Européen de l'Industrie de la Régénération (GEIR), "Waste Framework Directive revision: European waste oil re-refining industry position" (June 16, 2016), *available at* https://www.geir-rerefining.org/wp-content/uploads/GEIRpositionpaperWFD_2016_FINAL.pdf.
[40] *Id.*
[41] Arabian Oil and Gas, "UAE and Saudi Arabia leading GCC in waste oil refinement" (April 14, 2014), *available at* https://www.arabianindustry.com/petrochemicals/news/2014/apr/28/waste-oil-refining-in-the-uae-4678557/.
[42] 42 U.S.C. 6901 et seq.

equivalent items, in a fiscal year, to establish an affirmative procurement program for that item. RCRA section 6002(c)(1) requires procuring agencies to procure designated items composed of the highest percentage of recovered materials practicable, consistent with maintaining a satisfactory level of competition, considering such guidelines. Procuring agencies may decide not to procure such items if they are not reasonably available in a reasonable period of time; fail to meet reasonable performance standards; or are only available at an unreasonable price.[43]

There are 61 products designated in eight categories. EPA designates products that are or can be made with recovered materials and provides recommended practices for buying the products.[44] Once a product is designated, procuring agencies are required to purchase it with the highest recovered material content level practicable.[45] EPA has designated re-refined lubricating oils under the CPG program to include engine lubrication oil, hydraulic fluids, and gear oils. The designation specifically excludes marine and aviation oils. EPA recommends that procuring agencies set their minimum re-refined oil content standard at the highest level of re-refined oil that they determine meets the statutory requirements of RCRA Section 6002(c)(1), but no lower than 25 percent re-refined oil.[46]

EPA recommends that procuring agencies review their Federal procurement practices and eliminate those that would inhibit or preclude procurement of lubricating oils containing re-refined oil.[47] As of 2019, there are over 800 city, State, and Federal offices using lubricants that are made from re-refined base stock, including the U.S. Army Corps of Engineers, U.S. Department of the Army, U.S. Coast Guard, Federal Bureau of Investigation, U.S. Postal Service, and the New York City, Chicago, and Phoenix transit authorities.[48] Individual States have implemented various collection and recycling programs. Some states impose sales taxes to subsidize collections and classify used oil as hazardous waste to discourage illegal dumping, and some local municipalities fund collection activities to reduce improperly disposed used oil by DIY oil changers. The role of the Federal Government in used oil management and individual State programs are further discussed in Section VII.

Used Oil Programs in Other Nations

Worldwide perception of used oil management has evolved over recent years to reflect an increase in used oil collection and refinement. Although burning of used oil continues to occur, many nations and local governments have implemented various management and regulatory

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[43] Code of Federal Regulations, Title 40 – Protection of Environment, *available at* https://www.govinfo.gov/content/pkg/CFR-2012-title40-vol26/xml/CFR-2012-title40-vol26-part247.xml.
[44] U.S. Environmental Protection Agency, "Comprehensive Procurement Guideline (CPG) Program," (October 31, 2019), *available at* https://www.epa.gov/smm/comprehensive-procurement-guideline-cpg-program.
[45] *Id*.
[46] U.S. Environmental Protection Agency, "Comprehensive Procurement Guidelines for Vehicular Products," (February 6, 2019), *available at* https://www.epa.gov/smm/comprehensive-procurement-guidelines-vehicular-products#03.
[47] *Id*.
[48] Information provided by NORA.

programs to encourage the collection and refinement of used oil through incentives, collection mechanisms, and various legislation and penalties. Consumers are becoming more environmentally conscious and are increasingly more reluctant to dispose of used motor oil in non-environmentally friendly ways. Quality of re-refined oils in the marketplace is constantly improving and continuously being integrated into multiple motor oil blends. In global regions beyond the United States, used oil management programs have evolved differently, and no standard or "best practice" exists. Used oil management programs in different countries have largely evolved based on different perceptions of the local governments and consumers as to what the problem is and how best to collect and manage used oil.

Europe continues to develop environmentally driven initiatives to maximize used oil refining to produce base oils and has led the rest of the world in embracing the circular economy for lubricants. EU regulations establish general principles via Directives for used oil classification and the priorities for its use, but individual member states are obliged to transpose the Directives into national law and are free to establish their own regulations within the framework of the EU Directives. Used oil's hazardous waste classification and waste hierarchy encourage used oil refining. Extended Producer Responsibility (EPR) schemes are encouraged, with the burden imposed on the lubricant blender/marketer. Used oil burning is approved only within strict guidelines and only after demonstration that refining is infeasible.

Italy is the leading example of a managed used oil market that has gone well beyond the EU basics, introducing significant subsidies to encourage the collection and refining of used oil. The used oil market is administratively managed through an industry consortium (CONOU)[49] and funded through a "contribution fee" levied on lubricants producers. Funds are disbursed to approve used oil collectors and refiners, with the level of subsidies determined annually by CONOU. Other EU countries—such as Spain, Portugal, and France—have also introduced incentivized sectoral used oil management systems, which have fostered the growth of used oil refining. Some EU member countries, notably Germany and the United Kingdom (UK), rely on market forces to determine the appropriate level of used oil refining investment over time. Government taxing levies also have a substantial impact on used oil management. For example, in the UK, the total exemption of waste oil burning as a fuel makes waste oil very attractive for combustion processes, and this is the reason that the UK imports large quantities of waste oil from other EU countries and creates a shortage of raw material for re-refiners.[50] This is one distinguishing feature of the UK market compared to most other countries in Europe.

In Europe, the European Parliament considers waste oils to be any mineral, synthetic lubrication, or industrial oils that have become unfit for the use they were originally intended, such as used combustion engine oils and gearbox oils, lubricating oils, oils for turbines, and hydraulic oils. Additionally, the European Parliament considers regeneration of waste oils as any recycling

[49] The Italian Consortium for management, collection and processing of used mineral oils, to raise public awareness on the issues of collection and disposal of used oils.
[50] Taylor Nelson Sofres Consulting, "Critical Review of Existing Studies and Life Cycle Analysis on the Regeneration and Incineration of Waste Oils" (December 2001).

operation whereby base stocks can be produced by refining waste oils, in particular by removing the contaminants, the oxidation products, and the additives contained in such oils. In Europe, used oil refining to base stocks is referred to as "regeneration," and in Canada as "re-use."

Article 4 of the WFD (2008/98/EC) describes the hierarchy of waste options, giving preference to reuse with regard to disposal methods. The priority order in waste prevention and management is: (1) prevention; (2) preparing for re-use; (3) recycling; (4) other recovery, e.g., energy recovery; and (5) disposal. Article 4 further states that member states shall take measures to encourage the options that deliver the best overall environmental outcome. This may require specific waste streams departing from the hierarchy where this is justified by life cycle thinking[51] on the overall impacts of the generation and management of such waste.[52]

Article 21 of the WFD states that member states shall take the necessary measures to ensure that (1) waste oils are collected separately, unless separate collection is not technically feasible taking into account good practices; (2) waste oils are treated, giving priority to regeneration or alternatively to other recycling operations delivering an equivalent or a better overall environmental outcome than regeneration; and (3) waste oils of different characteristics are not mixed and are not mixed with other kinds of waste or substances, if such mixing impedes their regeneration or another recycling operation delivering an equivalent or a better environmental outcome than regeneration.[53] The European Parliament report on the WFD revision, adopted on March 13, 2017, includes provisions mandating an unconditional separate collection of waste oils, as well as the achievement of an 85 percent regeneration target by 2025.[54]

The EU's policy framework was founded on LCA studies performed by accredited independent organizations, such as the 2005 peer-reviewed LCA study by the Institut für Energie- und Umweltforschung GmbH (IFEU). In 2018, the IFEU study was updated to take into account changes in the European used oil collection and re-refining industry that had occurred since the 2006 study. The recent IFEU study confirms the findings of the 2006 study—that regeneration of used oil to base oils is a preferred outcome—and concludes that improvements in regeneration

[51] Life Cycle Thinking considers the range of impacts throughout the life of a product. Life Cycle Assessment quantifies this by assessing the emissions, resources consumed and pressures on health and the environment that can be attributed to a product. It takes the entire life cycle into account – from the extraction of natural resources through to material processing, manufacturing, distribution and use; and the re-use, recycling, energy recovery and the disposal of remaining waste. *See:* https://ec.europa.eu/environment/waste/publications/pdf/Making_Sust_Consumption.pdf.

[52] Directive 2008/98/EC of the European Parliament and of the Council on Waste and Repealing Certain Directives (November 19, 2008), *available at* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098

[53] "European Commission, Waste Framework Directive 2008/98/EC, *available at* https://ec.europa.eu/environment/waste/framework/.

[54] FuelsEurope, "FuelsEurope – Recommendation on the WFD revision ahead of trilogue (Waste Oils)" (September 4, 2017), *available at* https://www.fuelseurope.eu/wp-content/uploads/2017/11/FuelsEurope-recommendation-on-the-Waste-Framework-Directive-1.pdf.

technology applied in Europe since 2005 have further enhanced the beneficial contributions of regeneration relative to burning.[55]

European Petroleum Refiners Association division, FuelsEurope, whose members are all 40 companies that operate petroleum refineries in the European Economic Area in 2019, supports the implementation of responsible management practices for waste oils to protect public health and the environment. It also recognizes the need for a better understanding of the current market structure (i.e., flows, operations, and calculation methods at stake) and for a robust impact assessment before any targets can be set.[56] The association cautions against various amendments that are likely to provoke structural changes and unintended consequences for waste oil management, particularly when considering the specifics of well-established markets in various EU countries.[57] Competition for energetic recovery of waste oils through burning continues to be an issue that prevents further re-refining of waste oils across Europe.

In 2016, about 13 percent of all base oils consumed in the EU came from re-refined waste oils, and the other 87 percent were virgin base stocks produced from crude oil refining, mostly imported and produced by major global players. Western Europe relies heavily on base stock imports and meets approximately 17 percent of local demand (used oil re-refined to base stocks as percentage of lube consumed). The European Waste Oil Re-refining Industry Association, Groupement Européen de l'Industrie de la Régénération (GEIR), proposes an EU-wide target of 95 percent collection of waste oils of the produced and collectable waste oil in each member state, as well as an EU-wide target of reaching at least 60 percent of re-refined waste oils of the produced and collectable waste oil in all member states by 2020.[58] These proposed values would increase to 100 percent and 85 percent respectively by 2025. Some member states (e.g., Greece, Spain, and Italy) are already re-refining between 85 to 100 percent of waste oils. About 80 percent of Europe's waste oil re-refining industry is represented by GEIR, which is a sector group of the Union of the European Lubricants Industry (UEIL). UELI is the strongest representative body for independent manufacturers of lubricants in Europe. GIER is analogous to the Used Oil Refining Coalition in the United States.

EPR schemes in EU countries have been well-functioning for the waste oil industry. Usually, the EPR schemes are managed by a consortium that supports the collection, transportation, and management of waste oils. Depending on the EPR scheme and national legislation in place,

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[55] Groupement Européen de l'Industrie de la Régénération (GEIR), "Ecological and energetic assessment of re-refining waste oils to base oils: Substitution of primarily produced base oils including semi-synthetic and synthetic compounds" (September 25, 2019), *available at* https://www.geir-rerefining.org/ecological-and-energetic-assessment-of-re-refining-waste-oils-to-base-oils-substitution-of-primarily-produced-base-oils-including-semi-synthetic-and-synthetic-compounds/.

[56] FuelsEurope, "FuelsEurope – Recommendation on the WFD revision ahead of trilogue (Waste Oils)" (September 4, 2017), *available at* https://www.fuelseurope.eu/wp-content/uploads/2017/11/FuelsEurope-recommendation-on-the-Waste-Framework-Directive-1.pdf.

[57] *Id.*

[58] Groupement Européen de l'Industrie de la Régénération (GEIR), "Waste Framework Directive revision: European waste oil re-refining industry position" (June 16, 2016), *available at* https://www.geir-rerefining.org/wp-content/uploads/GEIRpositionpaperWFD_2016_FINAL.pdf.

obligations by the consortium to send waste oil for re-refining rather than energy recovery (burning) also exist. Examples of well-functioning EPR schemes include Italy, Spain, and Greece.[59]

Canada has delegated authority for used oil regulation to the individual provinces, which focus incentives on used oil collection. Federal used oil regulations are largely non-existent. Due to the provincial and territorial regulations surrounding used oil, it is unlikely that Canada will introduce Federal regulations duplicating what the provinces and territories have in place. Many of the provinces and territories have implemented their own regulations surrounding used oil. Inter-provincial cooperation of the provincial Used Oil Management Associations is formalized through the National Oil Material and Antifreeze Advisory Council (NUOMAAC), which coordinates Canada-wide used oil and antifreeze materials recycling efforts and encourages national standards. NUOMAAC's goal is to have fully integrated programs in all of Canada's provinces and territories. Each respective provincial used oil management association is funded by an Environmental Handling Charge (EHC) remitted by all retailers, wholesalers, or first sellers of lubricating products. EHCs range from $0.08–$0.17/gallon. A Return Incentive (RI) is paid to private sector collectors and processors to pick-up used oil and deliver it to government-approved recycling facilities. Each province is divided into zones, and the RI provides "Freight Equalization Zone Pricing," compensating collectors for the different costs of pick-ups of used oil anywhere in their respective provinces.

Countries within the Middle East have previously undervalued, discouraged, or overlooked the value of used oil. Within the Cooperation Council for the Arab States of the Gulf, waste oil refining is a relatively new consideration. The United Arab Emirates (UAE) and Saudi Arabia have led the increased focus on this practice. Being at the epicenter of oil production, historically, the region never saw the reason for re-refining waste oil. Many local governments discouraged it, as it was perceived as competition to the state-owned grease and lube manufacturers.[60]

In India, a very small percentage of waste oil is processed for re-refining. There are about 257 spent oil registered recycling facilities distributed across 124 districts and over 19 states with a total spent oil recycling capacity of 1.39 million tons. While India has a significant recycling potential, the major constraint faced in recycling waste/used oil is cost of the collection, storage, and subsequent transportation of the waste to the recycling unit.[61] According to the Karnataka State Pollution Control Board (the legal entity entrusted to control pollution in the Indian State of Karnataka), around 20,000–25,000 barrels of waste and used oil are generated in the state every month, but only 10 percent of it is received for reprocessing, and the remainder often is obtained

[59] *Id*.
[60] Arabian Oil and Gas, "UAE and Saudi Arabia leading GCC in waste oil refinement" (April 14, 2014), *available at* https://www.arabianindustry.com/petrochemicals/news/2014/apr/28/waste-oil-refining-in-the-uae-4678557/.
[61] P K Selvi, Mita Sharma, and J S Kamyotra, "Spent oil management and its recycling potential in India – inventory and issues," 2013 International Symposium on Environmental Science and Technology. Procedia Environmental Sciences, Volume 18 at 742-755 (2013).

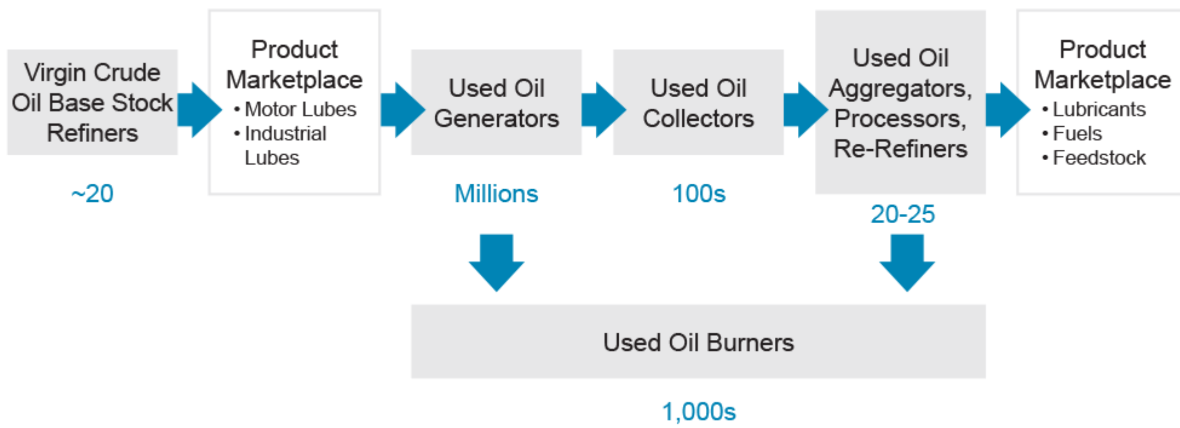
by the unorganized sector and is used for combustion fuel without being reprocessed. Additionally, roadside garages often let the used oil into drains and sewers, adversely impacting the environment and representing a lost reuse opportunity.[62]

[62] Rakesh Prakash, "Used engine oil makes its way to industries as fuel, pollutes air," The Times of India (Feb. 9, 2017), *available at* http://toi.in/e9MaHb.

V. Used Oil Sector Stakeholders

The used oil sector includes five primary stakeholder categories: Generators, Collectors, Aggregators/Processors/Re-refiners, Burners, and Virgin Crude Oil Base Oil Refiners (Figure 7). Other secondary stakeholder categories include Lubricant Retailers, Space Heater Manufacturers, Fuel/Lubricant Importers, and Exporters and Regulators. Each of these primary stakeholder groups are described below, with additional supporting material provided in Appendix C.

Figure 7. Used Oil Sector Stakeholders
(Number of entities in each group shown in blue)



Used Oil Generators

There are millions of used oil generators. These can be divided into two groups: used motor oil generators (oil from an internal combustion engine crankcase) and industrial oil generators. The first group includes every person who drives a car and either changes his or her own oil (a DIY generator) or takes their car to a garage or oil-change service location (a DIFM).

Oil change services, also known as "quick-lube" or "fast lube" services are defined in the industry as businesses that derive the majority of their sales from quick, convenient oil changes and other automotive preventative maintenance services that can be done in 30 minutes or less.[63] Within the industry, locations that have dual profit centers, like a car wash/fast lube, auto repair garage, muffler shop, tire stores or car dealerships with quick service lanes, are called "lube plus" shops.

Quick-lube and lube-plus locations account for significant volumes of used oil within the generator stakeholder group. This group also includes companies or Government agencies that

[63] Tammy Neal "Tops in the Industry Rankings," NOLN (July 1, 2019), *available at* https://www.noln.net/articles/3852-tops-in-the-industry-rankings.

maintain fleets of vehicles that use engine lubricating oil. For example, the various Federal agencies and branches of the military, bus and taxi companies, construction equipment operators, airlines, railroads and marine transportation firms. Included here also would be farmers and livestock ranchers who operate a wide variety of internal combustion engine driven equipment that require routine replacement of crankcase oil. The same enterprises that generate used motor oil can also generate used motor oil filters, used antifreeze, and used transmission, power steering and brake fluids, some of which is often mixed in with collected motor oil. Used motor oil has distinct properties, and there are efforts in place along the used oil collection chain to reduce the amount of mixing with non-motor oil fluids.

The second group includes a wide range of companies that use equipment that relies on a variety of oils as elements of manufacturing or production processes. These oils can include engine oils, compressor oils, electrical transformer oils, hydraulic oils, metal cutting or processing oils, as well as oily waste waters associated with these processes.

The used oil generated by these generating entities may be used onsite (in the case of used motor oil burned as space heater fuel), subsequently collected by companies in the collector category; or, in the case of motor oil DIYs, either taken to a central used oil collection location or disposed of in another manner. In all States, DIYs can take their used motor oil to DIFMs, State or local recycling centers, or lubricant sales outlets. While the level of convenience for DIYs seeking to recycle their used oil varies from State-to-State and location-to-location within States, opportunities for DIYs to recycle their used oil have grown significantly over the past decade.

There are a number of factors that influence the number of used motor oil generators and the amount of used motor oil that is generated and collected:

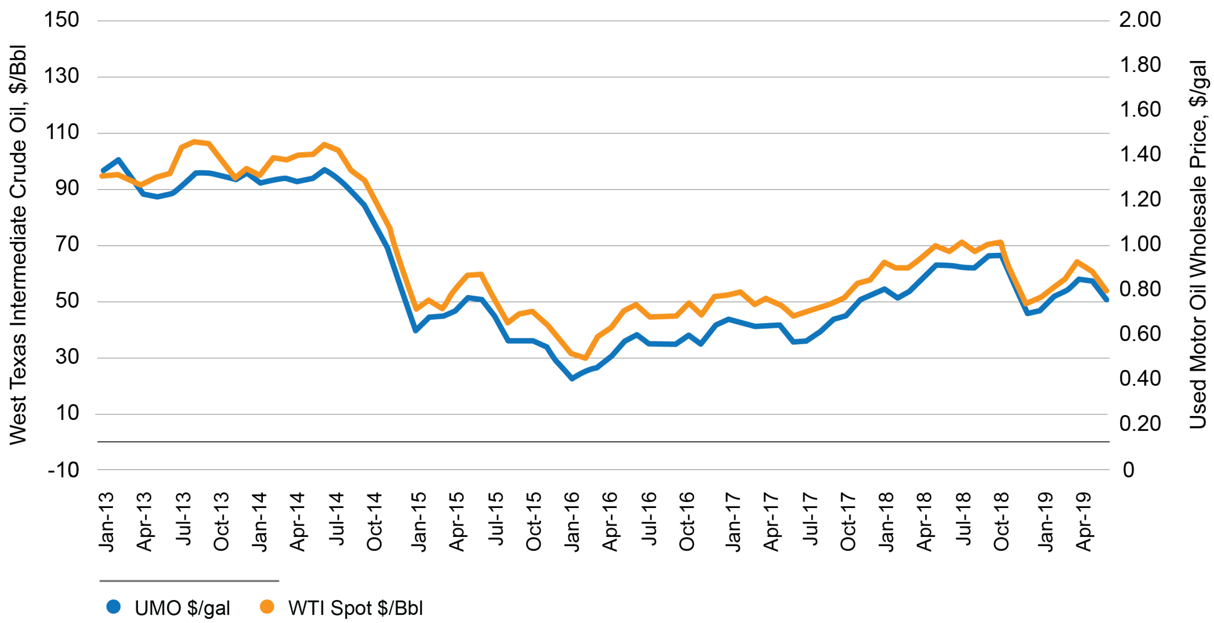
- **Value of the Used Oil** – Depending on the levels of supply and demand for used oil, collectors may either charge generators to pick up their used oil or pay them for the oil. If, for example, DIFMs and garages are charged by collectors to remove their used oil, they may be more likely to burn it as space heater fuel or limit the volumes of used oil they accept from DIYs. Collectors are constrained in what they can economically charge/pay by the value they receive for their used oil from the aggregators/re-refiners/processors, who, in turn, are constrained by the value they can charge for their products, which is primarily influenced by the impact on competitive products of the price of crude oil (see Figure 8).

  In the years prior to 2015–2017, depending on the size of their operation, many DIFMs and garages were getting an extra $1,200–$1,500 per month from the sale of used oil.[64] During 2015–2017, this situation reversed to where some operators were paying $1 or more per gallon for their used oil to be collected, and shops that were still getting paid for their used oil were getting only a fraction of what they had been. Because these enterprises are bound

[64] David Burbach, "From Asset to Liability: The Fall of Used Motor Oil," NOLN (July 1, 2016), https://www.noln.net/articles/1478-from-asset-to-liability-the-fall-of-used-motor-oil.

by law to recycle their used oil beyond what can be combusted onsite for space heating, they must accept this reversal of an income stream to a cost stream (more on this issue is in Section V).

Figure 8. Crude Oil and Used Motor Oil Price Relationship (2013–2019) [65]



- **Equipment Requirements** – Over time, vehicle engine manufacturers have made modifications that generally call for higher quality lubricants coupled with less frequent oil changes in new engines. As these vehicles become a larger portion of the national vehicle base, assuming the number of vehicles on the road does not increase dramatically, the volume of used oil available for collection should decline. However, there is some evidence that car owners are not modifying their behavior to reduce oil change frequency despite owner manual instructions.[66] In addition, an increase in the number of electric vehicles of all types (passenger cars and fleet vehicles) will lead to a decline in the volumes of motor oil used for combustion engine lubrication and thus in the volume of used oil available for collection. More on these trends is included in Appendix A.

[65] Crude oil price data from EIA (https://www.eia.gov/dnav/pet/pet_pri_spt_s1_m.htm), and UMO price data from Kline data provided to DOE (UMO price based on full 20,000 lb. truck load).
[66] Philip Reed, "Stop Changing Your Oil," Edmunds (April 23, 2013), *available at* https://www.edmunds.com/car-maintenance/stop-changing-your-oil.html.

- **Regulations** – State and local regulations require that DIFM and motor oil sales locations accept used motor oil for collection; regulations that constrain the circumstances under which used motor oil can be burned and penalties imposed for dumping may increase the volume of used oil collected.
- **Economic Conditions** – Economic recession can cause people to either delay oil changes to save on out-of-pocket costs or to increase oil change frequency to prolong the life of an existing automobile and delay a new car purchase. Reduced economic activity can lead to reduced transportation demand and a decline in used oil generation among fleets of all types. A decline in manufacturing can lead to a decline in the volumes of used industrial oils.
- **Level of State and Local Recycling Outreach** – Increased efforts by State and local jurisdictions or non-governmental organizations promoting recycling can influence the number of DIYs actively recycling their used oil and the ease of recycling.
- **Consumer Attitudes and Awareness** – Overall consumer attitudes about environmental stewardship and recycling have been trending toward increased levels of engagement in recycling over the past several decades.

DIFM quick-lube operations have expanded because of the convenience that they offer consumers both in terms of automobile maintenance and in avoiding the difficulties in disposing of their own used oil. The DIFM to DIY ratio has improved over the past 20 years to approximately 75 percent DIFM to 25 percent DIY for personal automobile oil changes.[67] According to one source, the quick-lube oil changing industry in the United States is valued at $7 billion and, since 2012, has achieved an annualized growth rate of 1.5 percent.[68]

National Oil and Lube News ranks 100 quick-lube-plus chains in the United States as including a total of 25,729 operating locations as of April 30, 2019 (14,591 company-owned locations, and 11,138 franchised locations).[69] Some of the more recognized quick-lube chains include Jiffy Lube (1929 locations), Valvoline Instant Oil Change (1224 locations), Pennzoil 10-Minute Oil Change (1050 locations), and Express Lane (1,000 locations).

In 2018, according to the most recent U.S. Census Survey of facilities that qualify as NAICS 811191,[70] the Automotive Oil Change and Lubrication Shop (quick-lube locations), the quick-lube industry location subset alone had 8,395 facilities that handled approximately 81,000,000 service visits. Assuming 90 percent of those service visits included an oil change, and the average passenger vehicle oil change generates between 4 to 7 quarts of used engine oil, the

[67] Communication to DOE from Kristy Babb, Executive Director of American Oil Change Association (AOCA), received November 15, 2019.
[68] Brandon Gaille, "25 Quick Lube Industry Statistics, Trends & Analysis," Brandon Gaille Small Business and Marketing Advice (June 1, 2018), *available at* https://brandongaille.com/25-quick-lube-industry-statistics-trends-analysis/.
[69] Tammy Neal "Tops in the Industry Rankings," NOLN (July 1, 2019), *available at* https://www.noln.net/articles/3852-tops-in-the-industry-rankings.
[70] NAICS: North American Industry Classification System.

quick-lube industry sector alone collected approximately 95 MMG of customers' used oil for recycling.

Most generators and collectors are not equipped to segregate higher valued used oil components like Group II+ or Group III used oils (see Appendix A for discussion of lubricant quality). Generators will ideally sell their used oil to the highest bidding collector, regardless of whether or not the collector is reselling to a burner or a re-refiner. Sales terms range from term contracts to spot sales and depend on many factors, including the seller's knowledge of the market. The price offered by the collector is a function of the transportation costs involved, the volume recovered, and value the collector can obtain for the used oil on delivery. Table 6 provides some additional insight into the recent trends in DIFM used oil collection economics. The percentage of DIFM operators that receive payment by licensed used oil transporters at its highest reported rate over the past three years is not even 1 percent of monthly gross revenue; and, even in the context of net monthly profit, it is also very small, at less than 4.2 percent. Monthly net profit for an average fast lube facility is in the range of $7,500 to $10,500.[71]

The Automotive Oil Change Association's (AOCA) 440 members also collect DIY used oil from members of the public. Prior to AOCA providing this service, millions of gallons of used oil were inappropriately disposed each year (e.g., down sewer drains, into landfills via trash cans, or dumped on the ground). Since the fast lube industry began collecting DIY used oil in the mid-1980s, many of those gallons of used oil have been collected for recycling. AOCA's 1999 DIY used oil collection survey of member facilities (at that time 2,800) showed approximately 1 MMG of DIY used oil collected annually. At that time the DIY marketplace was still majority (75 percent) oil change service over DIFM (25 percent). Twenty years later, the marketplace has reversed to approximately 75 percent DIFM versus 25 percent DIYer. AOCA's current survey reflects that flip in nearly twice the number of facilities participating but with the same overall 1 MMG collection rate. Fewer DIYers means fewer gallons of DIYer used oil to manage. See Appendix C for additional information on Used Oil Stakeholders.

About 76 percent of survey respondents collect less than 1 gallon of DIY used oil at each facility per month; 23 percent of respondents collect up to 100 gallons of DIY used oil at each facility per month; and only 1 percent of respondents collect over 100 gallons of DIY used oil at each facility per month.[72] Fast lube operators with the highest reported DIY used oil collection volumes are located in Kentucky, North Carolina, and South Carolina.[73]

[71] Communication to DOE from Kristy Babb, Executive Director of AOCA, received November 15, 2019.
[72] Submission to DOE from Kristy Babb, Executive Director of AOCA, received November 15, 2019.
[73] AOCA, December 2019 Government Affairs Update, *available at* https://www.aoca.org/page/Dec2019GAUpdate.

Table 6. DIFM Statistics on the Economics of Used Oil Collection Arrangements, 2017–2019 [74]

	2017	2018	2019
Average number of oil changes per day per location	34.0	30.0	34.5
Average amount of used oil generated per month (gallons) based on average of 5.24 quarts per change	1,069	943	1,085
Share of Fast Lube operators receiving payment for used oil (average payment per gallon)	1%	28%	57%
Average amount received by operator and payment per gallon	$245 ($0.23)	$311.25 ($0.33)	$314.65 ($0.29)
Used oil revenue as a share of monthly net profit	3.26% or less	4.15% or less	4.19% or less
Share of Fast Lube operators that paid transporters to take used oil for recycling (average payment per gallon)	65%	5%	11%
Average amount paid to transporter and payment per gallon	$224.50 ($0.21)	688.53 ($0.73)	na
Used oil transport cost as a share of monthly net profit	3% or less	9.18% or less	na
Share of Fast Lube operators that used transporters to transport used oil for recycling without payment or charge	34%	67%	32%

This public service activity of accepting DIY used oil increases daily costs to quick-lube operators in terms of storage, employee time and training, and added costs of used oil contamination by DIY mixtures, including the costs of cleaning and/or replacing storage equipment and resulting fines. For their public service efforts, fast lube operators receive protection from off-site, third-party liability under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Service Station Dealer Exemption (SSDE).[75] However, unfortunate legislative drafting tied the 1986 SSDE to Federal used oil management standards that weren't effective until March 8, 1993. The delay meant almost seven years' worth of collected DIY used oil was simply added to fast lube operators' gallonage totals at off-site,

[74] Sourced from the NOLN Fast Lube Operator Surveys 2017, 2018, & 2019 (*see* https://www.noln.net/products/category/272).
[75] U.S. Environmental Protection Agency, "Guidance: Superfund's Service Station Dealers Exemption*, available at* https://www.epa.gov/enforcement/guidance-superfunds-service-station-dealers-exemption.

third-party used oil recycling-turned-Superfund sites[76] because CERCLA is otherwise a strict liability statute. Per CERCLA, although there may be only one actual "polluter" at a given site, any generator of waste[77] lawfully transported there can be held liable for the total costs of cleanup. Of the approximately 62 known used-oil-recycling-related Superfund sites across 26 States, 42 percent operated from 1986–1993, resulting in fast lube owners being responsible for millions of dollars in contribution claims and legal fees. Additional details on this topic are provided in Appendix C.

Collectors

Used oil collectors act as intermediaries, transporting used oil between the generators and the aggregators/processors/re-refiners. They perform a vital service for the industry, and their business is very competitive. Industry estimates indicate that there are 350–400 used oil collection companies in the United States.[78] Most companies in the used oil collection business are privately held, but several are publicly traded. Some companies are national or super-regional, but the majority are local or regional companies. Since 2006, the collection sector of the used oil business has seen major mergers- and acquisitions-driven consolidation.

The primary factors impacting the collectors' profit margins are the pickup volumes collected and the distances that must be traversed to pick up the used oil and deliver it to the aggregator/processor/re-refiners. As the individual parcel volumes diminish and as the distances increase, the ability for a collector to maintain a profit margin erodes. Hence, this part of the business is very much a matter of collection efficiency. These companies typically employ from 1 to 50 trucks to collect oil from the various generating sources. In some instances, they pay the generator for their used oil; and, in other instances (depending on volume, distance, and quality), they charge a fee to the generator to pick up the oil. Gathering is typically a highly competitive, marginal business that is influenced by market fluctuations. The collector must find a margin between the generator and the used oil end user. The generator wants to dispose of the used oil in the most economical manner, whereas the "end user" does not want to pay more than necessary.

When the value of used oil has fallen with oil prices, collection companies have been able to maintain profit margins through more sophisticated, data-driven collection logistics, as well as through the trend toward larger parcel volumes at increasing numbers of DIFM quick lube pick up locations. Collectors running fleets of tank trucks that can generally hold between 2,000-

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[76] EPA's Superfund program is responsible for cleaning up some of the Nation's most contaminated land and responding to environmental emergencies, oil spills, and natural disasters. A Superfund site is any U.S. land that has been contaminated by hazardous waste and identified by EPA as a candidate for cleanup because it poses a risk to human health and/or the environment.

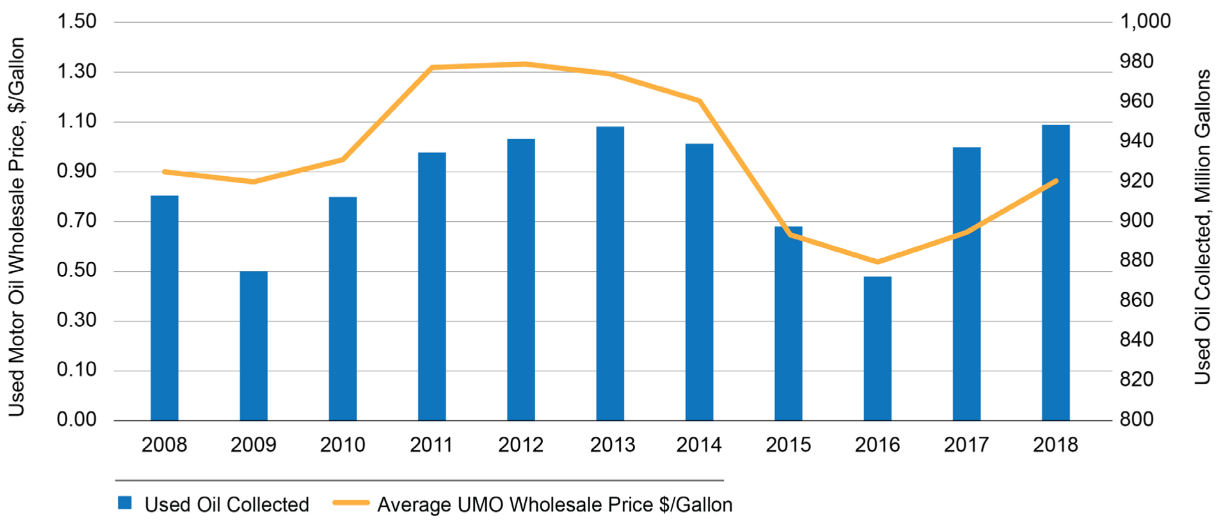
[77] Used oil is a presumptive, non-hazardous waste only while it is destined for recycling. Once released to the environment, the presumption is gone, which is how the generator of a non-hazardous waste can later be connected to a hazardous waste Superfund site.

[78] Data provided by UORC.

4,000 gallons average about 322 gallons per stop in the United States.[79] A collector typically has a defined radius of operation that will allow for the most cost-effective operation for collecting the used oil from generator clients and delivering it to aggregator/processor/re-refiner clients. Used oil collected beyond the economic collection radius for refining is typically exchanged with other net buyers or channeled to burning applications.

Used oil collection is influenced by crude oil price movements. When oil prices collapsed in 2015–2016, many collectors began charging for used oil pickup as used oil netback values for generators became negative. This led to some generators opting for alternative uses including space heater burning or improper disposal methods. As a result of these factors, commercial used oil collection declined by at least 5 percent from pre-2015 levels. Nevertheless, used oil collections have remained fairly flat at about 900 MMG per year for the past decade (Figure 9).

Figure 9. Used Oil Collections, 2009–2018 [80]



Some re-refiners and processors also act as collectors. Table 7 lists the estimated volumes of used oil collected by major companies in 2017. The table shows that of the 937 MMG collected in 2017 in the United States by 350+ companies, about 326 MMG (35 percent) was collected by four integrated aggregator/processor/re-refiner parent companies; about 240 MMG (26 percent) was collected by 15 large national or super-regional companies; and 371 MMG (40 percent) was collected by roughly 320–370 small and mid-sized companies that sell the majority of their collected volumes to aggregators.

[79] Data provided by NORA.
[80] Kline & Company data provided to DOE.

Table 7. Distribution of Used Oil Collections among Major Collecting Companies in 2017–2018 [81]

Category	Company	Parent	HQ Location	Also Re-refiner or Processor	2017 (MM Gallons)
4 UORC Co.'s	Safety-Kleen (incl. Thermo Fluids)	Clean Harbors	Richardson, TX	Yes	326
	Heritage-Crystal Clean	-	Indianapolis, IN	Yes	
	Universal Environmental Services (UES)	Avista	Peachtree City, GA	Yes	
	Heartland Petroleum	Vertex Energy	Houston, TX	Yes	
	H&H Oil		Baytown, TX	Yes	
	TOTAL				**326**
15 Large Collectors (≥10 MM gallons)	Demenno-Kerdoon	World Oil	South Gate, CA	Yes	45
	Noble Oil Services	-	Sanford, NC	Yes	30
	Aaron Oil	-	Mobile, AL	-	20
	Holston Environmental Services	-	Chattanooga, TN	-	15
	Lorco Petro. Srvcs.	-	Elizabeth, NJ	-	15
	Northstar Environmental Group	-	Gallatin, TN	-	15
	Valicor	-	Dexter, MI	-	15
	Texpar Energy	-	Onalaska, WI	-	13
	Jebro	-	Sioux City, IA	-	12
	Cliff Berry, Inc.	-	Fort Lauderdale, FL	-	10
	Environ. Specialists	-	Youngstown, OH	-	10
	Flex Oil Service	-	Channelview, TX	-	10
	Necessary Oil	-	Bristol, TN	-	10
	Synergy Recycling	-	Winter Haven, FL	-	10
	Western Oil	-	Lincoln, RI	-	10
	TOTAL				**240**
Re-Refiners / Regenerators	ORRCO, Como, Hydrodec, Rock Canyon, and Others	-	Various	Some	30
5 Large Waste Management Firms	Waste Management, Veolia, Tradebe, Covanta, and Another	-	Various	-	25
20 Mid-sized Collectors	Mid States, Spirit, Enterprise, Georgia Petroleum, etc.	-	Various	-	80
300 to 350 Small Collectors	-	-	Various	-	236
GRAND TOTAL					**937**

[81] Kline & Company data provided to DOE.

Used Oil Processors

Once collected, a variety of processes may be applied to used oil to transform it into usable products. Generally, used oil refining (or re-refining) is the term used to define processing that renders a primary final base stock product that can be used as the principal blending component in a lubricant. However, plants that subject the used oil to less severe processing are employed to produce heavy distillates, and the operators of these facilities are grouped into the category of "used oil processors." There is a dozen or so of these companies currently operating in the United States. The oldest and largest plant has been operating in California since 1928. Seven of these plants started up within the last 10 years; however, three of these are currently idle.

Thermal distillation or chemical treatment processes employed in these plants are designed to produce heavy distillates, including vacuum gas oil (VGO), marine diesel oil (MDO), or cutter stocks,[82] which are primarily channeled to crude oil refineries where they are converted in catalytic cracker or hydrocracking units (severe processing) or used for blending into fuel oil. VGO/MDO plants can often, with the addition of back-end hydrotreating, be converted to base stock production. Moreover, used oil refineries at times may elect to run only the front end of their facilities and produce VGO/MDO if the price spread between base stocks and VGO/MDO do not support full utilization of re-refining capacity. Hence, there is some overlap between the categories of "used oil processor" and "used oil re-refiner."

In addition, pre-treatment of used oil, consisting of various degrees of removal of solids (using filtration and centrifuging) and removal of excess water and contaminants, like antifreeze (using distillation), may be employed to produce a heavy fuel oil often referred to as processed fuel oil (PFO) or recycled fuel oil (RFO). Plants of this sort are also grouped into the "used oil processor" category. Table 8 provides a list of used oil processors producing heavy distillate fuel oils with their location and fuel oil production capacities. Total capacity is about 332 MMG per year, of which, about 254 MMG per year (77 percent) is currently operating. About 50 percent of the total domestic capacity has been added within the past 10 years.

Some used oil processors focus solely on specific used oil feedstocks like electrical transformer oils or industrial oils, regenerating those feedstocks for the market that produces them. In some cases, regeneration takes place on site; and, in some cases, the oil is transported to a central plant and processed. Some of these processors link their facilities to their industrial customers and have evolved innovative techniques to allow them to recycle used oils almost indefinitely. Table 9 provides a list of the operating plants for this subset of processors, which have a total capacity of about 18 MMG per year. The table excludes smaller-scale mobile transformer oil regeneration services (e.g., Southwest Electric of Oklahoma City, Oklahoma). Also, the table

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[82] Cutter stock is any hydrocarbon that is blended to reduce the viscosity of the resulting blend, most commonly in fuel oil blending. In refineries, high-viscosity residual fuel oil product must be blended with such lower-viscosity material to meet the viscosity specification of the fuel oil. Common cutter stocks for fuel oil blending are diesel and kerosene, which are significantly more valuable than the resulting fuel oil blend, so refiners look for ways to minimize the amount of refined cutter stock in the finished blend. Processed used oil is one option.

does not include plants previously purposed for used oil regeneration, such as the Consolidated Recycling plant in Troy, Indiana, and Mid-America Distillations in Hot Springs, Arkansas. These were purchased by the ORG-CHEM Group and are now dedicated 100 percent to antifreeze and chemical recycling. Further, the Wallover Oil Industrial oil plant at Strongsville, Ohio, was shut down in 2010 and no longer processes used oil.[83]

Table 8. Operating and Idle Used Oil Processor Plants with Heavy Distillate Production Capacities as of August 2019 [84]

Status	Company	Parent	Plant Location	Start Date	Used Oil Feed Capacity (MM gals/yr.)
Operating	Demenno-Kerdoon	World Oil	Compton, CA	1928	100
	Omega Refining	Vertex Energy	Marrero, LA	1993	60
	Noble Oil	-	Sanford, NC	2009	43
	Synergy Hydrocarbon Recovery	-	Kingsland, GA	2016	24
	Emerald Services	Clean Harbors	Tacoma, WA	2013	18
	ORRCO	-	Portland, OR	2003	8
	Rock Oil Refining	-	Stratford, WI	2012	1
				Total Operating Capacity	**254**
Idle (as of August 2019)	TopSail Energy	-	Baytown, TX	2018	40
	TCEP	Vertex Energy	Baytown, TX	2009	30
	Intergulf Corporation	-	La Porte, TX	2014	8
				Total Idle Capacity	**78**
				Total Capacity	**332**

Overall, used oil processors serve a wide range of end user markets and utilize both used motor oils and industrial oils as feedstock. Some used oil processors mildly treat the used oil to create feedstocks for crude oil refineries or for sale as industrial burner fuel. Hot mix asphalt plants, for example, have been one of the largest consumers of used oil derived burner fuel in the United States. Similar processes are used to manufacture a wide range of industrial fuels for large-scale operations like steel mills, cement kilns, and utility boilers.

[83] Kline & Company information provided to DOE.
[84] Kline & Company data provided to DOE.

Table 9. Operating Used Oil Regeneration Plant Capacity as of August 2019 [85]

Feedstock	Company	Parent	Plant Location	Start Date	Used Oil Feed Capacity (MM gals/yr.)
Transformer Oil	Hydrodec	-	Canton, OH	2008	11.3
	EPS Industries	-	Wheeling, WV	1981	2.5
	Environmental Management Systems (EMS)	-	Phoenix, AZ	1998	2.3
			Transformer Regeneration Capacity		**16.1**
Industrial Oil	General Oil	Aevitas	Detroit, MI	2000	2.0
			Total Regeneration Capacity		**18.1**

Used Oil Re-refiners

Used oil re-refiners apply severe processing to collected used oil feedstocks to produce a final product (base stock) that can be used as a principal blending component in lubricants.

The impact of motor oil additives is a key consideration that drives processing severity. Performance-enhancing additives (including inhibitors and viscosity index improvers) can contribute up to 15 to 25 percent by volume of motor oil lubricants, whereas industrial oils typically contain much lower concentrations of additives (in the range of 2 to 5 percent). These additives become degraded during the oil's use and must be removed from the oil during the re-refining process to produce a suitable base stock.

Modern base-stock-producing used oil refineries typically consist of two primary processing stages after pretreatment to remove solids, water, and contaminants:

1. *Thin film evaporation under vacuum (vacuum distillation)* to produce a VGO-like base stock precursor and to separate other less valuable fractions (lighter distillates) of used oil; and
2. *"Polishing"* that involves hydrogenation, solvent extraction, or clay treatment to produce API-specification base stocks, mainly Group I and II.

The more intense processing facilities are more expensive to design and construct and more expensive to operate than simpler processing facilities.

[85] Kline & Company data provided to DOE.

Another factor in the technology needed for used oil re-refining is the trend in motor oil quality improvement, which is expected to continue and poses unique challenges for used oil re-refiners. The lubricants industry (both virgin lube refining and used oil re-refining) have faced a series of quality improvement initiatives during the last 20 years, driven primarily by tightening fuel economy standards and the desire to maintain efficient lubrication from the beginning to the end of a motor oil application cycle. The trend toward smaller engines that operate at higher engine revolutions per minute also contributes to the need for better motor oil quality. These quality requirements have been met by a variety of investments to produce enhanced quality base stocks that support extended oil drain intervals.

Fortunately, as higher quality motor oils become more popular in the market, the quality of used oils, and thus the re-refiner's feedstock, is also improving. This trend enhances the re-refiner's ability to manufacture higher quality base stocks. Also, from an economic point of view, as the quality of both used oil and re-refined oil increases, re-refining economic operating margins will also improve. These quality trends do not significantly impact the economics of used oil processing for combustion (fuel oil), which are determined simply by the heating value of the used oil and not its quality. This positive trend will continue to motivate re-refiners to seek the highest quality feedstock and provide the highest quality product possible to the market and also serve to support the investments needed to accomplish this.

It should be noted that used oil re-refining is not solely limited to producing base stocks for motor oil applications. Re-refined base stocks can be used in any of several thousand different formulations of lubricating oil products besides motor oil—ranging from automotive transmission fluids, which is the next largest volume demand component, to industrial oils, which include hydraulic oils, metal working fluids, marine lubricants, compressor oils, heat transfer oils, process oils, and greases. Also, motor oils comprise many quality grades, just as there are many different types of engines and different levels of quality requirements. Over time, the quality trends will continue to improve, but there will likely always be a wide range of quality requirements that will be candidates for blending with re-refined oils.

As of 2019, there are 13 operating used oil refineries producing base stocks in the United States. The largest six together represent 89 percent of the Nation's installed capacity (Table 10). The two largest re-refineries, both located in Indiana (East Chicago and Indianapolis) near established rail lines, are operated by Clean Harbors (Safety-Kleen) and Heritage Group (Heritage-Crystal Clean) and together they account for about half of total U.S. capacity.

About 50 percent of the re-refined lube oil production capacity online, available or under construction has been completed within the last 10 years (Figure10). Mesa Petroleum is building a small plant in Belen, New Mexico. This is the only new capacity currently planned. Additional capacity could be generated by upgrading current VGO/MDO plants.

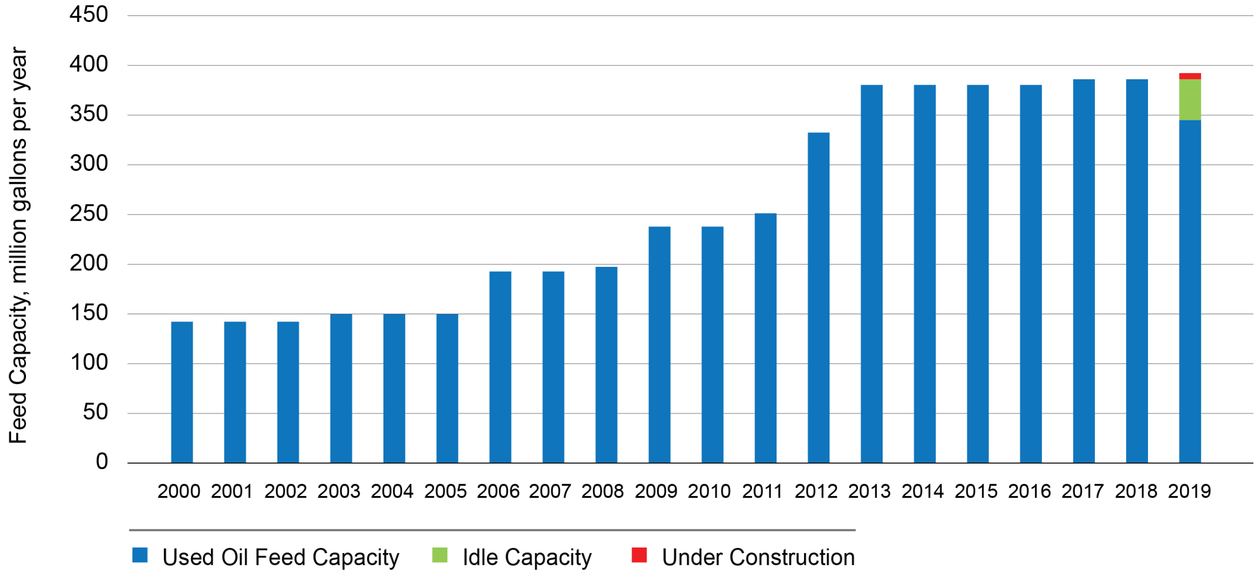
Table 10. Operating, Idle and Under Construction Used Oil Re-refining Plants for Base Stock Production as of August 2019 [86]

Status	Company	Parent	Plant Location	Start Date	Used Oil Feed Capacity (MM gals/yr.)	Base Oil Production Capacity (MM gallons/yr.)			
						G I	G II/II+	G III	Total
Operating	Safety-Kleen	Clean Harbors*	East Chicago, IN	1991	117	-	78.18	-	78.18
	Heritage-Crystal Clean	Heritage Group*	Indianapolis, IN	2012	75	-	48.75	-	48.75
	UES	Avista*	Peachtree City, GA	2013	48	-	30.6	5.4	36.00
	Bango Refining	Clean Harbors*	Fallon, NV	2006	32	-	21.46	-	21.46
	Heartland Petroleum	Vertex Energy*	Columbus, OH	2009	20	-	17.00	-	17.00
	Universal Lubricants	Clean Harbors*	Wichita, KS	2009	18	-	12.26	-	12.26
	Olein Recovery	-	Yabucoa, PR	2006	10	-	6.98	-	6.98
	Ecolube Recovery	-	Portland, OR	2003	7.7	-	5.37	-	5.37
	Green View Tech.	-	Rollinsford, NH	2012	6.0	-	4.26	-	4.26
	Rock Canyon Oil	-	American Fork, UT	2008	5.6	4.65	-	-	4.65
	Rational Energies	-	Plymouth, MN	2017	5.5	3.85	-	-	3.85
	Como Lube	-	Duluth, MN	2009	1.5	1.04	-	-	1.04
	Rock Oil Refining	-	Stratford, WI	2012	1.0	0.25	-	-	0.25
			Total Operating Capacity		**347.3**	**9.79**	**224.86**	**5.4**	**240.05**
Idle (August 2019)	Evergreen Oil	Clean Harbors	Newark, CA	1987	2.7	-	18.40	-	18.40
	Southeastern Petroleum	-	Chester, SC	2011	13.7	9.20	-	-	9.20
			Total Idle Capacity		**16.4**	**9.20**	**18.40**	**-**	**27.60**
Under Con-struction (August 2019)	Mesa Oil Recycling	-	Belen, NM	2019	5.6	4.65	-	-	4.65
			Total Under Construction Capacity		**5.6**	**4.65**	**-**	**-**	**4.65**
			Total		**369.3**	**23.64**	**243.26**	**5.4**	**272.30**

*UORC member.

[86] Kline & Company data provided to DOE.

Figure 10. Used Oil Re-refining Capacity at U.S. Used Oil Refineries, 2000–2019 [87]

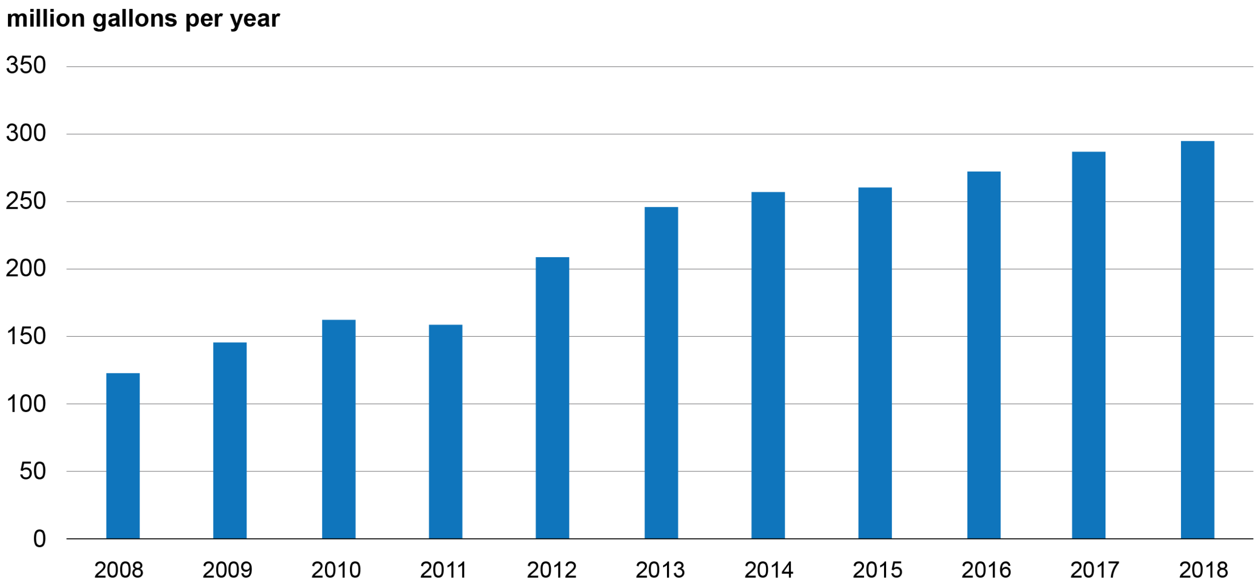


In the 1960s, some 125–150 used oil refineries were estimated to be operating in the United States, producing about 300 MMG/year of base stock.[88] By 1971, the number of used oil refineries had dropped to 45, with a corresponding drop in base stock production to 120 MMG. Concurrent deregulatory activity removed the so-called "Small Refiner Bias," and almost all U.S. used oil refineries had closed by the mid-1970s. Plants that were closed during this time were relatively small and employed acid-clay treatment processes, which had become environmentally unacceptable. Base stocks produced from used oil refining at that time were of poor quality and unreliable supply, and they were sold at significant discounts to base stocks refined from virgin crude oil.

Today, the estimated volume of used oil feed being processed to produce base stock in U.S. used oil refineries is 294 MMG per year, approaching the volumes seen during the 1960s (Figure 11). This production level represents a maximum effective utilization factor of operating base stock from used oil re-refining capacity of about 85–90 percent, similar to virgin crude oil refineries, due to planned maintenance and other factors. Used oil re-refineries have been running close to maximum effective capacity in recent years.

[87] Based on Kline & Company data provided to DOE.
[88] Teknekron, Inc. for the U.S. Environmental Protection Agency, "A Technical and Economic Study of Waste oil Recovery," (1973).

Figure 11. Estimated Volumes of Used Oil Feed Being Processed to Base Stock in U.S. Used Oil Refineries [89]



Used Oil Burners

Collected used oil can be legally combusted as a fuel in three ways:

1. Businesses that are generators of used oil (quick-lube services, commercial garages and service stations, vehicle fleet garages, etc.) may burn on-site generated used oil in space heaters to provide heat for their operations. These space heaters generally use about 1–2 gallons per hour. While the 2006 report referenced 75,000 units based on a trade association estimate, a current manufacturer estimates 100,000 such units operating nationwide, although sales have slowed since 2009.[90]
2. Used oil collectors may sell unprocessed used oil directly to industrial end users (cement kilns, asphalt plants, etc.) for use in their plants as a lower cost alternative to fuel oil. These plants typically employ baghouse filters to control the release of particulates in the exhaust from used oil combustion.
3. Re-refiners and processors may choose to process collected used oil into fuel oil for sale to end users as an alternative to fuel oil or MDO refined from virgin crude oil.

EPA's regulations in the United States Code of Federal Regulations 40 CFR part 279 (40 CFR part 279) contains directions related to the burning of used oil. Used oil is defined as on-spec or off-spec based on certain standards for flash point and levels of arsenic, cadmium, chromium,

[89] Based on Kline & Company data provided to DOE.
[90] "Used Oil Generation, Collection & Management Options/System," Presentation to DOE by Scott D. Parker of NORA and Scott Miller of Safety-Kleen, October 2019.

lead, and total halogens specified in the EPA's 40 CFR part 279. Generators may burn used oil in oil-fired space heaters provided that: (a) the heater burns only used oil that the owner or operator generates or burns used oil received from household DIY used oil generators; (b) the heater is designed to have a maximum capacity of not more than 0.5 million Btu per hour; and (c) the combustion gases from the heater are safely vented to the outside ambient air.[91] Used oil processors/re-refiners also may burn a portion of their used oil feedstock for the purposes of processing the larger portion of the used oil feedstock.

Under 40 CFR part 279, off-specification used oil may be burned for energy recovery in the following devices:

- **Industrial Furnaces** – Cement kilns, lime kilns, aggregate kilns, phosphate kilns, coke ovens, blast furnaces, smelting, melting or metal refining furnaces, titanium dioxide chloride process oxidation reactors, methane reforming furnaces, pulping liquor recovery furnaces, combustion devices used in the recovery of sulfur values from spent sulfuric acid, and halogen acid furnaces.
- **Boilers** – A unit designed for recovering and exporting thermal energy in the form of steam, heated fluids, or heated gases, including industrial boilers located on the site of a facility engaged in a manufacturing process where substances are transformed into new products, as well as utility boilers used to produce electric power, steam, heated or cooled air, or other gases or fluids for sale.
- **Space Heaters** – Operated by used oil generators within the constraints outlined above.

Used oil generators are given the opportunity to use collected oil as a fuel for space heating, regardless of its content. Appendix C provides additional details on the use of space heaters.

Used oil burners are key end users of recycled oils, and their decision-making is primarily dependent on the relative cost of alternative fuels, natural gas, or fuel oil refined from virgin crude. Wholesale used oil prices are typically discounted compared to virgin liquid fuels or natural gas (on a heating value parity basis), reflecting the quality considerations of the fuels in question. These discounts reflect market factors, distances from source, and quality considerations (Figure 12). The relatively low natural gas prices over the past decade (Figure 13) have made used oil less competitive compared to natural gas on a Btu basis and have significantly reduced the demand for used oil in the industrial furnace and boiler markets where low priced gas is an option.

[91] 40 C.F.R. § 278.23 (1993).

Figure 12. Average U.S. Wholesale Used Motor Oil (UMO) Price and High Sulfur Fuel Oil (HSFO) Price History, $/gallon, 2013–2019 [92]

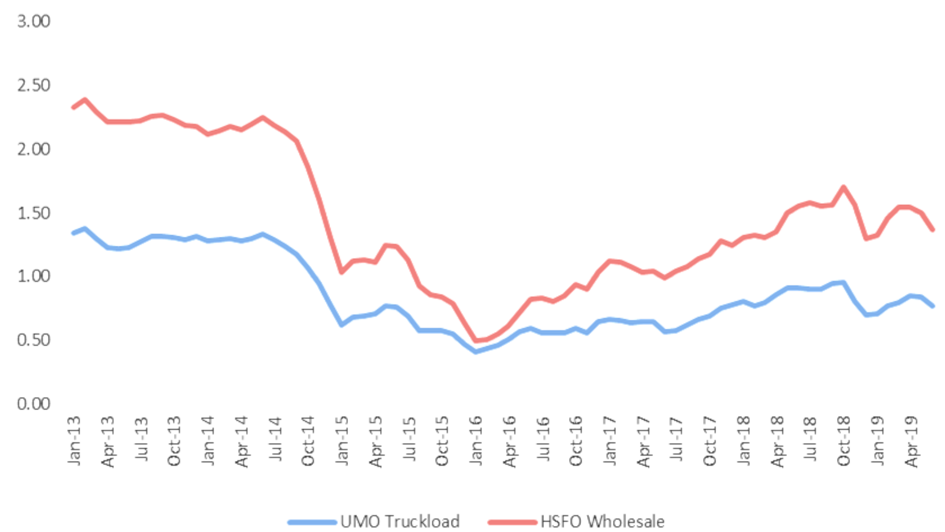
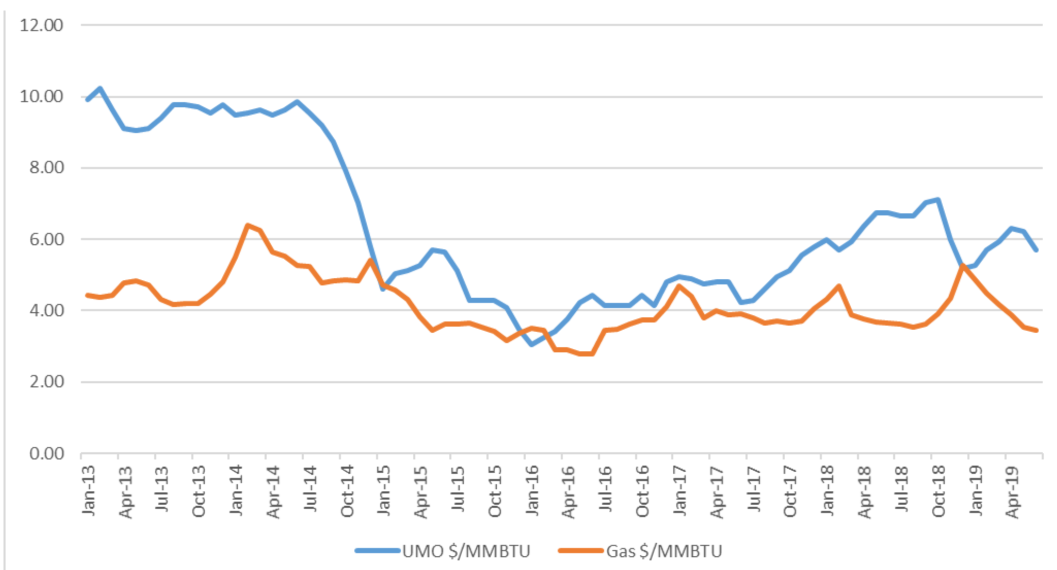


Figure 13. Average U.S. Industrial Natural Gas Price and Average UMO Price in $/MMBtu, 2013–2019 (assumes 135,000 Btu/gallon UMO energy value) [93]



[92] Kline & Company data provided to DOE (UMO price based on full 20,000 lb. truck load, and HSFO price is wholesale refiner price for residual fuel oil with >1 percent sulfur).
[93] Kline & Company data provided to DOE; U.S. Energy Information Administration, "United States Natural Gas Industrial Price" (Jan. 31, 2020), *available at* https://www.eia.gov/dnav/ng/hist/n3035us3m.htm.

Another factor in the decision-making of generators with the option to burn a portion of collected used oil is the value offered (or charged) by the collector. If a used motor oil generator (e.g., a quick-lube service) is well paid for the used motor oil by a collector, the motivation to burn that used oil for space heating will be reduced. If they are instead charged per-gallon fees by the collector for pick-up of the used motor oil, the motivation to burn the oil for space heating will be greater. Collectors may be disadvantaged when wholesale prices offered for their used motor oil by processors and re-refiner's fall, forcing them to charge for pick-up rather than pay for product. Table 11 shows the relationship between nationwide average prices (or charges) for UMO at quick-lube service generator locations and wholesale prices paid for used oil by re-refiners. The data show that since 2016, the motivation to burn used oil in space heaters may have increased, and that, on average, collectors charged quick-lube services for pick-up in 2015-2016. The data presented earlier in this section support this trend but hints that recently more than half of DIFM operators are again being paid for their used oil.

Table 11. U.S. UMO Prices Paid by Collectors to DIFMs Compared to Prices Paid by Re-refiners to Collectors, 2002–2017 ($/gallon) [94]

Year	Price Received for UMO by DIFMs	Wholesale Price for Full Truckload of UMO paid by Re-refiners	Margin
2002	0.12	NA	NA
2003	0.12	NA	NA
2004	0.13	NA	NA
2005	0.39	0.65	0.26
2006	0.54	0.85	0.31
2007	0.76	0.78	0.02
2008	0.51	0.90	0.39
2009	0.53	0.86	0.33
2010	0.94	0.95	0.01
2011	1.41	1.32	-0.09
2012	1.35	1.33	-0.02
2013	1.41	1.29	-0.12
2014	0.29	1.19	0.90
2015	-0.44	0.64	1.08
2016	-0.14	0.54	0.68
2017	0.05	0.66	0.61

[94] Kline & Company data provided to DOE. NOLN data is for previous year price data (i.e., 2018 NOLN survey reports 2017).

A driving force behind the loss of value for used oil is the price of crude oil. During 2015–2017, the spot price of West Texas Intermediate (WTI) crude oil averaged only $47.58 per barrel, compared to $95.07 during 2012–2014.[95] It is difficult to determine where the break-even point is when it is economic to recycle old oil as opposed to refining new crude, but it is likely somewhere in the neighborhood of $55–$65 per barrel.[96] EIA's AEO2020 reference case projects U.S. crude oil prices will remain in the range of $74 to $93 per barrel between 2021 and 2030 (in $2018).[97]

Crude Oil Refiners

While not part of the used oil generation-collection-processing pathway in the used oil sector, crude oil refiners do play an important role in the overall dynamics and economics of the industry and are stakeholders in the sense that they produce the lubricants that will eventually become the used oil feedstock for the re-refining industry, as well as the lubricant base stocks and middle distillates that the processed used oil will compete with in the market place. Most importantly, the 13 operating used oil refineries compete directly on price and quality with 19 virgin base stock plants embedded in conventional domestic crude oil refineries.

Total net U.S. lubricant production by refiners and blenders (all lubricants, not just base stock) has remained fairly steady at between 150 and 180 thousand barrels per day (MBPD) (2,300 and 2,759 million gallons per year or MMGPY) over the past two decades (Figure 14).

Over that same time period, both exports and imports have risen fairly steadily. Overall, the net of lubricant production plus imports less exports has declined slightly, averaging 134 MBPD (2,054 MMGPY) over the 2000–2019 time period, but averaging 128 MBPD (1,962 MMGPY) over the past five years (Figure 15).[98] However, the share of U.S. lubricant supply coming from imports has risen from 3 percent in 2003, to 35 percent in 2018, and is now between 40 and 45 MBPD (613–690 MMGPY).

[95] U.S. Energy Information Administration, "Cushing OK WTI Spot Price FOB" (Feb. 20, 2020), *available at* https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RWTC&f=A.
[96] David Burbach, "From Asset to Liability: The Fall of Used Motor Oil," NOLN (July 1, 2016), *available at* https://www.noln.net/articles/1478-from-asset-to-liability-the-fall-of-used-motor-oil.
[97] Annual Energy Outlook 2020, *available at* https://www.eia.gov/outlooks/aeo/data/browser/#/?id=12-AEO2019&sourcekey=0.
[98] MBD: Thousand Barrels Per Day; MMGPY: Million Gallons Per Year.

Figure 14. U.S. Total Lubricant Production, Exports and Imports, 2000–2018 (MBPD) [99]

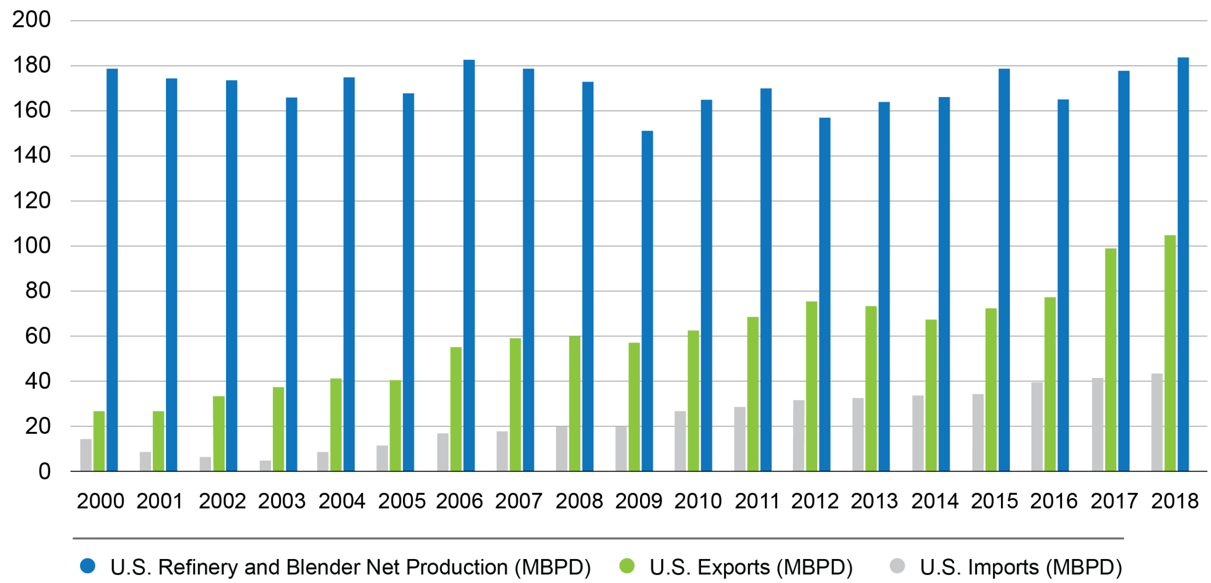
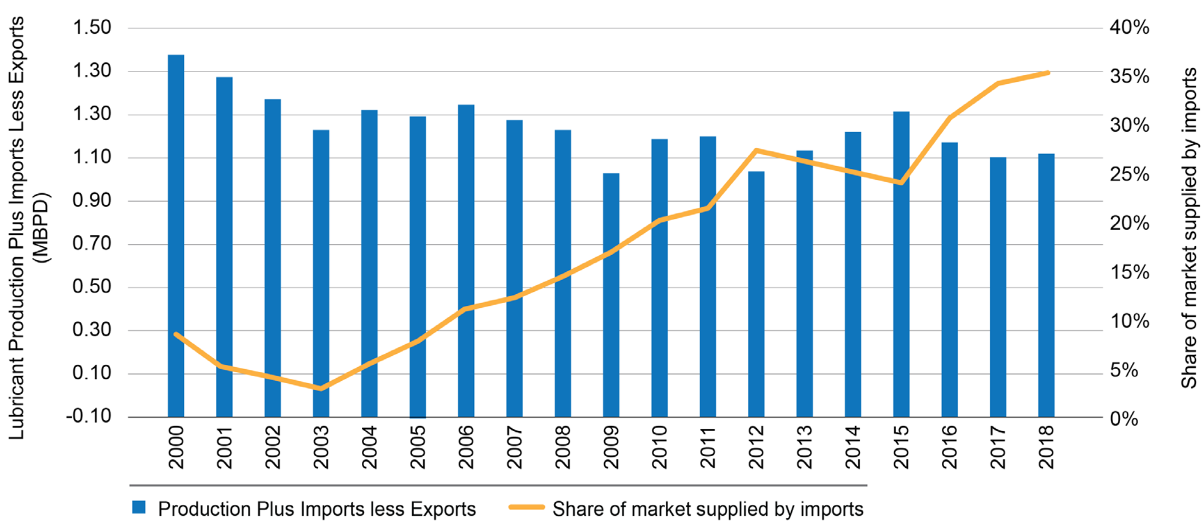


Figure 15. U.S. Lubricant Market Share Supplied by Imports [100]



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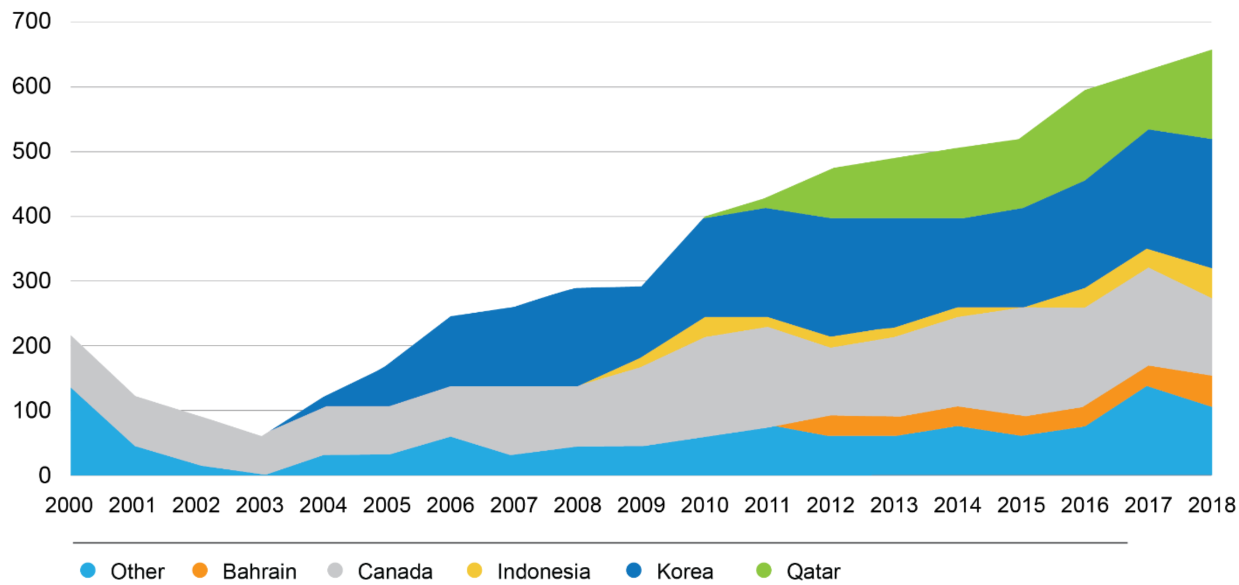
[99] U.S. Energy Information Administration, "Petroleum and Other Liquids Data Summary Page," *available at* https://www.eia.gov/petroleum/data.php. Total lubricant imports, *available at* https://www.eia.gov/dnav/pet/pet_move_imp_dc_NUS-Z00_mbblpd_a.htm,; total lubricant exports, *available at* https://www.eia.gov/dnav/pet/pet_move_exp_dc_NUS-Z00_mbblpd_a.htm and U.S.https://www.eia.gov/dnav/pet/pet_move_exp_dc_NUS-Z00_mbblpd_a.htm; and U.S. refiner and blender net lubricant production data, *available at* https://www.eia.gov/dnav/pet/pet_pnp_refp_dc_nus_mbblpd_a.htm.

[100] U.S. Energy Information Administration, "Petroleum and Other Liquids Data Summary Page," *available at* https://www.eia.gov/petroleum/data.php. Data from sources noted for Figure 14. Lubricant production plus imports less exports is calculated from data in Figure 14. Estimated share of market supplied by imports is calculated by dividing imports by the result of production plus imports less exports. This calculation does not take into account changes in inventories.

In 2018, total U.S. lubricant imports (Figure 16) came from nine countries, but the large majority (84 percent) were imported from only five: Korea (30 percent), Qatar (21 percent), Canada (19 percent), Indonesia (7 percent), and Bahrain (7 percent).[101]

Figure 16. U.S. Lubricant Imports by Country, 2000–2018 (MMGPY) [102]



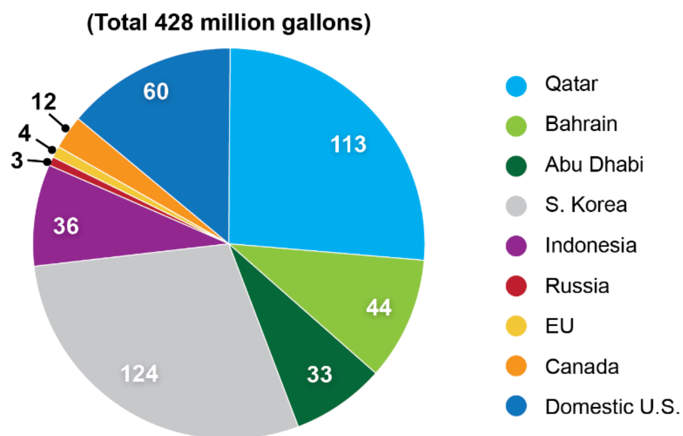
In 2018, U.S. demand for Group III / III+ lubricants was estimated at 428 MMG. However, U.S. refineries are not currently directed toward the production of Group III / III+ lubricants. Accordingly, unlike Group II base stocks, where the United States is a key exporter to global markets, the United States currently imports more than 85 percent of its Group III / III+ base stock needs (Figure 17).[103] The countries that supply Group III / III+ lubricants to the United States are primarily the same exporters noted above: Korea (29 percent), Qatar (26 percent), Canada (3 percent), Indonesia (8 percent), UAE (8 percent) and Bahrain (10 percent).

The reason U.S. crude oil refiners do not choose to produce a greater share of Group III / III+ lubricant demand is due to economics; they require more severe processing and are more costly to produce, providing lower overall margins. However, during 2016–2018, several virgin crude oil refiners announced plans to begin producing Group III base stocks: Calumet Specialty

[101] IEA, https://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_eppl_im0_mbblpd_a.htm
[102] U.S. Energy Information Administration, "Petroleum and Other Liquids Data Summary Page", *available at* https://www.eia.gov/petroleum/data.php.
[103] Kline & Company data provided to DOE.

Products Partners,[104] Motiva Enterprises,[105] and Petro-Canada Lubricants (acquired in February 2017 by HollyFrontier).[106] Further, in June 2019, Chevron announced that it would begin producing Group III base stock at its Richmond Refinery in California for Finland's Neste Corporation.[107] The capacity for North American production of Group III base stock by crude oil refiners appears to be showing signs of increasing in the face of market demand.

Figure 17. U.S. Supply of Group III / III+ Base Stocks (Million Gallons, 2018) [108]



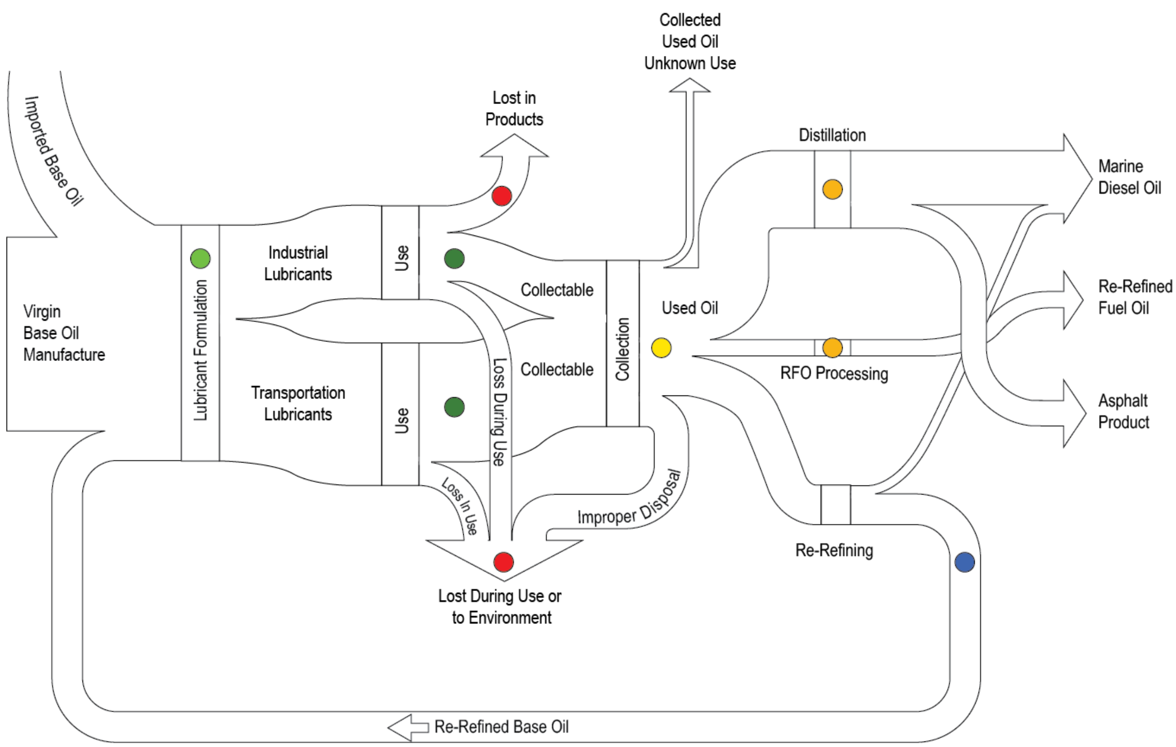
In addition, one of the used oil re-refining companies, Avista Oil, began producing Group III Base stock at its Peachtree City, Georgia, plant in 2016, using solvent extraction technology. Currently, Avista Oil is producing about 7 MMGPY of Group III base stock at that plant.[109] Used oil re-refiners indicate that they are well positioned to increase production of Group III quality oils from used oil feedstocks through modifications to their production processes, particularly as the volume of Group III oil in collected used oil rises as a greater share of late model cars requiring Group III lubricants enter the pool of vehicles operating in the United States.[110]

[104] Calumet Specialty Products Partners, "Calumet Specialty Products Partners, L.P. Announces Launch of Group III Synthetic Base Oil" (May 1, 2017), *available at* http://calumetspecialty.investorroom.com/2017-05-01-Calumet-Specialty-Products-Partners-L-P-Announces-Launch-of-Group-III-Synthetic-Base-Oil.
[105] Hydrocarbon Engineering, "Motiva Adds Base Oils to its Portfolio" (December 2017), *available at* https://www.hydrocarbonengineering.com/product-news/04122017/motiva-adds-base-oils-to-its-portfolio/.
[106] Independent Commodity Intelligence Services, "OUTLOOK '18 Americas base oil industry moves into Group III use" (January 2018), *available at* https://www.icis.com/explore/resources/news/2018/01/05/10177259/outlook-18-americas-base-oil-industry-moves-into-group-iii-use/?redirect=english.
[107] Fuels and Lubes Daily, "Chevron to produce Group II+ and Group III base oils in its U.S. refineries" (June 24, 2019), *available at* https://www.fuelsandlubes.com/chevron-produce-group-ii-group-iii-base-oils-u-s-refineries/.
[108] *Ibid.*
[109] Avista Oil, as provided in UORC presentation to DOE, October 16, 2019.
[110] Used oil re-refiner input at DOE Used Oil Study Stakeholder meetings held in September and October 2019.

Industry Overview

An integrated overview of used oil industry stakeholders can be represented with a Sankey diagram, showing component inputs, outputs, and flow paths across the various sectors described above. A precise Sankey representation of the volumes of flows across the entire U.S. used oil sector is currently impossible due to data limitations. Figure 18 provides a rough approximation of relative flow volumes through the used oil sector (based on a Sankey diagram based on 2010 data for the State of California alone).[111]

Figure 18. Sankey Diagram Showing Relative Volumes of Material Flows through Used Oil Sector*



*Colors correspond to Table 12.

Table 12 provides estimates of some of the key flows in this system based on analysis done by Kline and presented to DOE. This data shows that:

- Total U.S. lubricant consumption is just under 2,500 MMGPY and has held steady over the past decade.
- Lubricant losses-in-use are estimated to average about 16–17 percent of oil consumed for consumer auto, about 22 percent for commercial auto and about 68 percent for industrial use. These numbers are to be considered rough estimates, as they are not well

[111] Modified after diagram presented by PD Consulting at meeting with DOE on September 4, 2019.

constrained. Total estimated losses-in-use average about 1,100 MMGPY, or about 44 percent of the oil used.

- Losses-in-use are volumes of oil consumed as part of the lubrication process (e.g., burned in two-stroke engines, leaked from engines) or, in the case of industrial oil, lost to the environment during use (e.g., consumed process oils, absorbed in machine shop rags). Additional details on this category are provided in Appendix C.
- Used oil generated from both automotive and industrial use and available for collection averages just under 1,400 MMGPY, or about 38 percent of the oil used.

Table 12. Estimates of Key Elements of Total U.S. Used Oil (UO) Process Flow (Million Gallons) [112]

Metric	Detail	2008	2010	2012	2014	2016	2018
Lubricants Consumption	Total Lubricants	2,516	2,413	2,448	2,462	2,479	2,469
Estimated Lubricant Loss in-Use Percentages	Total Losses-in-Use	1,094	1,082	1,075	1,082	1,090	1,091
Used Oil Generated	Total Automotive (UMO)	1,020	943	974	978	985	972
	Total Industrial	402	405	399	402	404	406
	Total UO Generation	1,422	1,349	1,373	1,380	1,389	1,378
Used Oil Collected	Total Collected	913	912	942	939	872	949
Used Oil Feed for Re-refining	Total Feed for Base Oil Only	123	163	209	258	273	294
Base Stock Production Used Oil	Base Stock Produced from Used Oil	na	na	na	na	205	215
Used Oil Feed for Re-refining to Non-Base	Used Oil for Refining to VGO or MDO & Regeneration to Industrial Oils	94	133	168	183	178	196
Used Oil Accounted For at Source	Burned by Generators, Recycled On-site or Otherwise Disposed of	509	436	431	440	517	429
Used Oil Collected but not Refined	Burned as UO, Processed to RFO,Blended into HSFO or exported	696	616	565	498	421	459

[112] Based on Kline & Company data provided to DOE. Kline & Company is a global provider of consulting services and market intelligence. The data shared with DOE is a compilation of public and private data collected and analyzed by Kline & Company. It includes estimates of volumes that are currently unreported, based on the professional insights of the Kline & Company team of lubricant market experts. This data was provided to DOE during the stakeholder meetings held to collect information for this report.

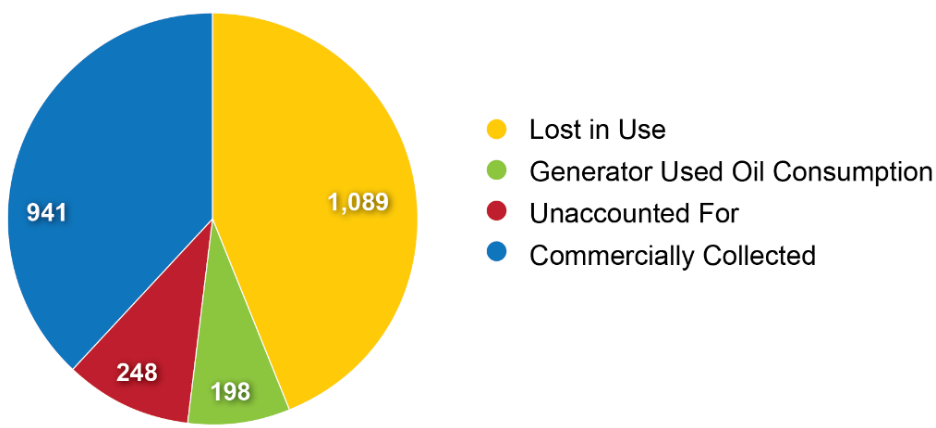
- Of the used oil available for collection, an average of about 900–950 MMG has been collected annually over the past decade, about 70 percent of collectable used oil. This volume has remained fairly flat.
- In 2018, of the 949 MMG of used oil collected, 294 MMG (31 percent) was re-refined to produce lubricant base stock. This percentage has increased from about 13 percent in 2008, which is in line with an accompanying increase in base stock re-refining capacity. In 2018, this resulted in 215 MMG of base stock production.
- Also, in 2018, of the 949 MMG of used oil collected, 196 MMG (21 percent) was processed to produce VGO / MDO or regenerated industrial oils. This percentage has increased from about 10 percent in 2008 to about 20–21 percent in 2016.
- In 2018, the volume of used oil unaccounted for at source (e.g., burned in space heaters by generators, recycled onsite, or disposed of in some other manner, including DIY disposal in landfills or dumped into storm sewers, etc.) was estimated to be 429 MMG or about 31 percent of the used oil generated. This percentage is estimated to have remained fairly constant, in the 30–35 percent range, over the past decade. Based on data provided by the space heater industry, between 80 and 120 MMG of collected used oil is burned annually in space heaters by used oil generators (see also Appendix C).[113] This amounts to between 18 percent and 28 percent of the estimated volume of used oil collected in 2018.
- In 2018, the volume of used oil collected but not re-refined into lubricant base stocks or other re-refined products (i.e., burned as used oil in industrial plants, processed to fuel oil, blended into high sulfur fuel oil, or exported as used oil for combustion in other countries) was about 459 MMG or about 48 percent of collected used oil. This percentage is estimated to have dropped steadily over the past decade—from 76 percent in 2008, to 48 percent in 2018. This shift is believed to be a result of increased used oil to lubricant base stock re-refining capacity and the shift to natural gas as a fuel in industrial plants.

[113] Provided by Rock Energy Systems, LLC, October 2019.

VI. Analysis of Used Oil Disposition

In 2017, an estimated 38 percent of the 2,476 MMG of U.S. lubricant demand was collected commercially as used oil; 44 percent was lost in use; 8 percent was consumed at source by generators; and nearly 10 percent is unaccounted for (as shown in Figure 19).[114] Lubricant losses-in-use and consumption quantities are often difficult to accurately estimate, as stakeholders are often unable to quantify data and often treat data as proprietary. U.S. used oil has stabilized toward 900 million to 1 billion gallons per year, as U.S. lubricant consumption has remained relatively flat in the past decade.[115] Used oil collection efficiency is gradually increasing due to an increased DIFM share of the oil change market and improved collection logistics and scheduling.

Figure 19. Estimated U.S. Lubricant Disposition in 2017 (Million Gallons)



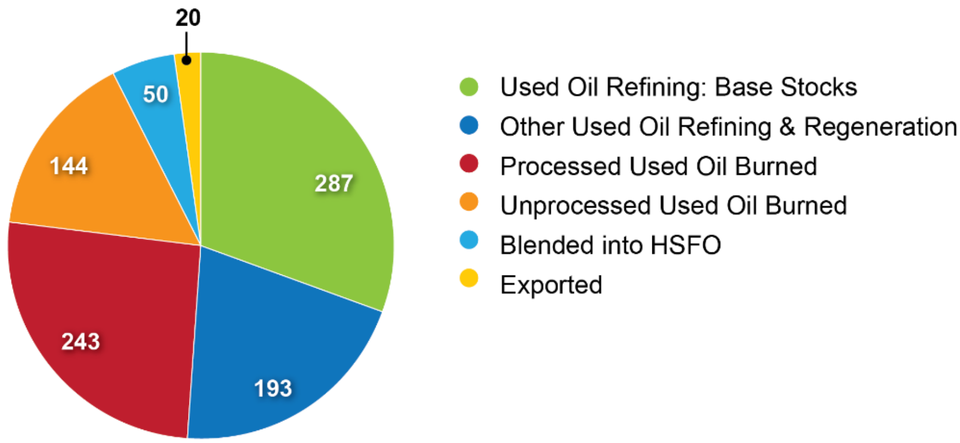
Used oil collection is often influenced by crude oil price fluctuations. When oil prices collapsed in 2015 to 2017, many collectors introduced “charge for oil” programs as used oil netback values for generators became negative. Some generators responded by finding alternative uses of the collected used oil, including improper disposal. As a result, commercial used oil collection declined by at least 5 percent from pre-2015 levels.[116]

Complete recovery of used oil is impractical due to onsite regeneration of primarily industrial used oils, onsite burning in licensed and unlicensed used oil burners, and collection deficiencies in remote areas where collection facilities are not conveniently located.[117] Of the estimated 937 MMG of used oil collected in 2017, 480 MMG, or 51 percent was refined; 387 MMG, or 41

[114] Adapted from “Used Oil Sources and Uses, An Overview of the U.S. Market,” Meeting on Beneficial Reuse Options for Used Lubricating Oil. Kline & Company, October 16, 2019.
[115] *Ibid.*
[116] *Ibid.*
[117] *Ibid.*

percent was burned; 50 MMG, or 5 percent was blended into HSFO; and 20 MMG, or 2 percent was exported (Figure 20).[118]

Figure 20. Estimated Disposition of U.S. Used Oil Collected in 2017 (Million Gallons)



Refined used oil to base stocks accounts for an estimated 287 MMG, and an additional estimated 180 MMG of used oil was processed in VGO/MDO re-refineries to produce refinery cracker feed, or heavy distillates for blending into marine and other fuels. A further 13 MMG were directed to offsite generation of spent industrial lubricants of mainly transformer oils. An estimated 20 MMG of used oil was exported—either directly or as-is, or indirectly through blending into HSFO for export to non-marine utility and industrial plants overseas.[119]

U.S.-based oil re-refining capacity has more than doubled from 2008 at approximately 150 MMG, to approximately 350 MMG per year of used motor oil feed in 2019 (Figure 21), as U.S. processing of used oil has followed suit through 2018 (Figure 22).[120]

[118] *Ibid.*
[119] *Ibid.*
[120] *Ibid.*

Figure 21. U.S. Base Stock Re-Refining Capacity, 2008 to 2019

(Million Gallons/Year of UMO Feed)

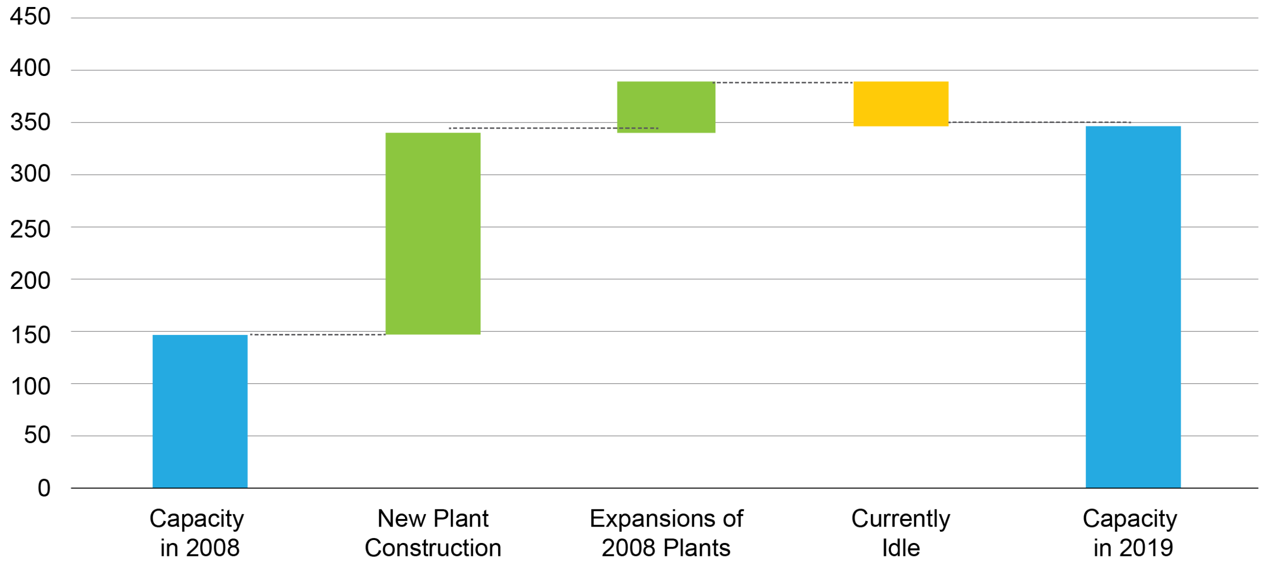
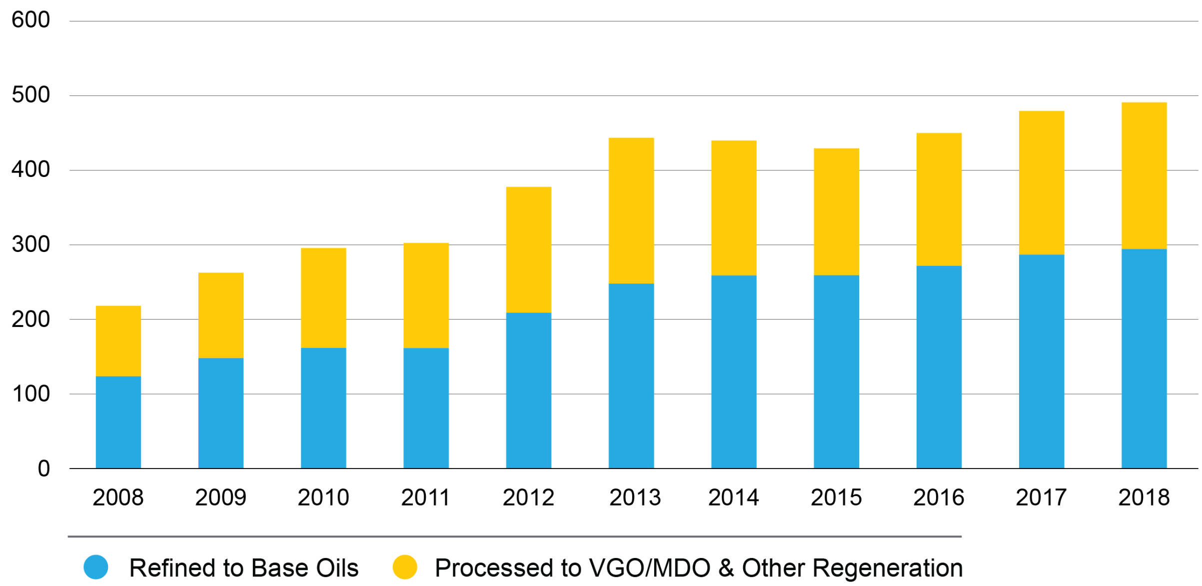


Figure 22. U.S. Processing of Used Motor Oil, 2008 to 2018

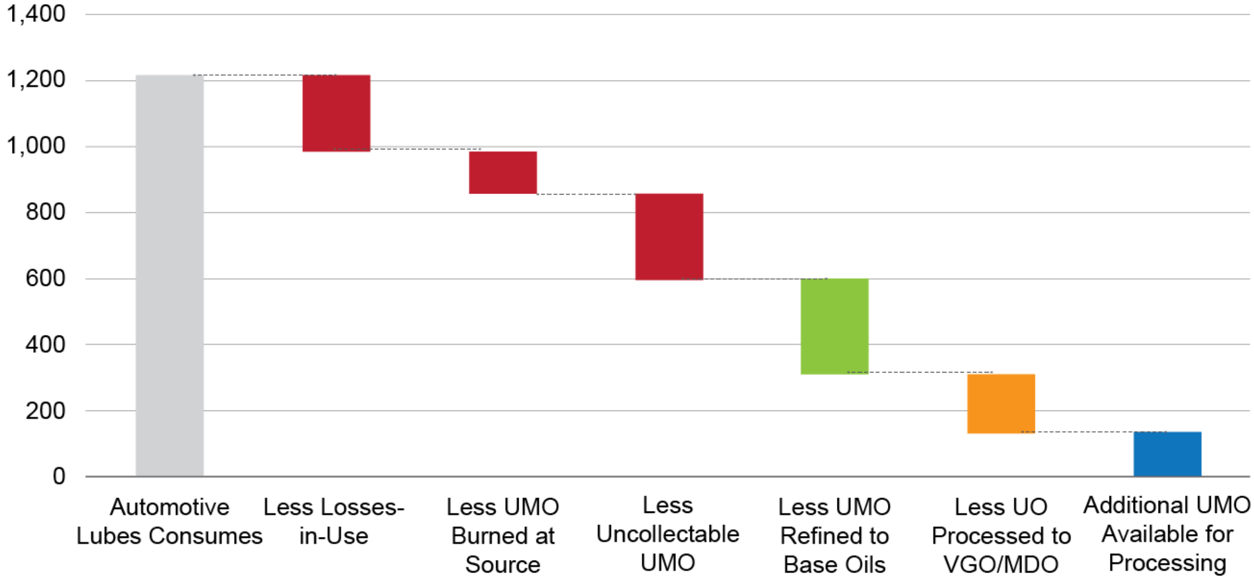
(Million Gallons of UMO Feed)



Even with today's challenges to collect used motor oil to oil re-refineries, there is enough premium feed available to double the current processing of used motor oils to base stocks (Figure 23).[121]

[121] *Ibid.*

Figure 23. U.S. Consumption of Automotive Lubes and Used Motor Oil Disposition in 2017 (Million Gallons) [122]



Nearly 87 percent of used motor oils collected are re-refined into base stocks, asphalt flux, and other recycled materials, and the remaining 13 percent is used as plant fuels, naphtha, and distillates (Figure 24).[123] Asphalt flux containing residual lubricant additives is most typically routed to roofing asphalt manufacturing, though smaller volumes enter the road construction and repair market where they are mixed with conventional paving materials. By-product distillates and lighter materials are used for plant fuel or sold to refiners or wholesalers for fuel processing and blending.

DIY / DIFM Volume Trends Update

A 2016 survey of 2,000 people in the United States indicated that only 29 percent are "completely confident" in their ability to change their own oil, whereas 23 percent were "not very confident," and 36 percent were "clueless."[124] Of those surveyed, only 31 percent of younger millennials born between 1992 and 1998 were "completely confident" in their ability to add coolant or water to a radiator in an overheated car compared to 60 percent of baby boomers born between 1946 and 1964. According to NBC News, millennials may not have the same degree of manual knowledge of cars as their parents, but, on average, have a stronger grip on technological knowledge and have easy access to online tutorials.[125] As a result, millennials are more prone to seek lube shops, dealerships, or vehicle warranties instead of changing their own oil. Additionally, as newer car engine technology develops, the mileage between oil changes

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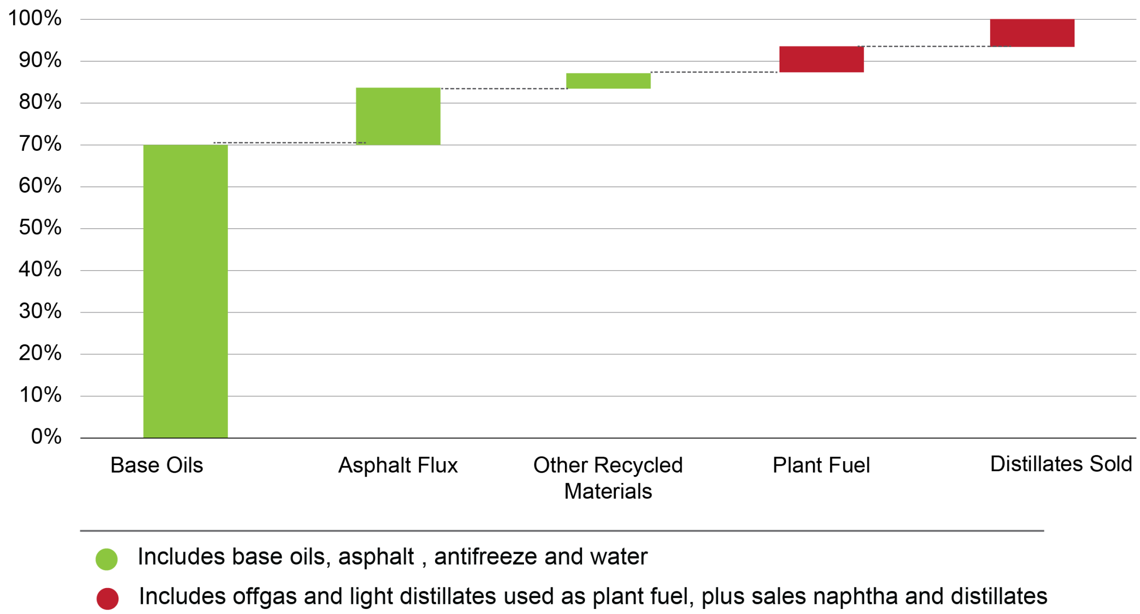
[122] *Ibid.*
[123] *Ibid.*
[124] "America's Automotive IQ: Analyzing Automotive Knowledge in the U.S." CheapCarInsurance.net (September 19, 2016), *available at* https://www.cheapcarinsurance.net/americas-automotive-iq/.
[125] NBC News, "60 percent of People Can't Change a Flat Tire – But Most Can Google It," (September 27, 2016), *available at* https://www.nbcnews.com/business/consumer/draft-60-%-people-can-t-change-flat-tire-most-n655501.

continually increases, and the frequency of oil changes decreases. Many car dealerships include customary oil changes, and in combination with a younger and less mechanically inclined generation, the trend for DIY oil changes are becoming more limited to older drivers and car enthusiasts.

Figure 24. Used Motor Oil Re-Refining Product Yields and Applications



According to a recent IBIS World report, the oil change services industry had an annual growth of 2.8 percent from 2014–2019, with 2019 revenues approaching $8 billion across 33,481 businesses employing 93,198 people.[126] Healthy revenues are in part due to reduced crude oil prices, which have contributed to greater car ownership and less dependence on ridesharing and public transportation. The additional use has resulted in increased need for oil changes. In a 2018 survey of 1,700 facilities and shops in all 50 States, fast lube operators averaged 30 oil changes a day, with an average cost of goods for a conventional oil change at $15.90 and $29.29 for a fully synthetic oil change, and an average vehicle age of 8.3 years with 102,442 miles.[127]

On average, operators charged $37.32 for an oil change with 5 quarts of conventional oil and $74.39 for an oil change with 5 quarts of fully synthetic oil. Approximately 28 percent of operators were paid for their used oil, 5 percent were charged for their oil, and 67 percent were neither charged nor paid for their used oil. Paid operators averaged $0.33 per gallon of used oil and charged operators paid $0.73 per gallon of used oil removed.

With a robust oil change services market and a new driver generation that prefers to outsource oil changes, a shift in preference from DIY to DIFM services is growing.

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[126] IBIS World, "Oil Change Services Industry in the U.S. – Market Research Report" (June 2019), *available at* https://www.ibisworld.com/united-states/market-research-reports/oil-change-services-industry/.
[127] NOLN, "2018 Fast Lube Operator Survey Results" (2018), *available at* https://www.rowleys.com/2018-fast-lube-operator-survey-results/2018-noln-operator-survey/.

Recent Trends and Outlook in Used Oil Burning Utilization Regarding Asphalt Plants, Cement Plants, and Marine Bunkers

Used oil is burned in industrial applications for thermal heating properties, as well as integrated as an active component in the production of asphalt. According to the Asphalt Pavement Alliance, the United States has more than 2.2 million miles of paved roads, and about 93 percent of them are surfaced with asphalt.[128] Historically, the largest use of recycled fuel oil was as fuel for the production of hot mix asphalt, although recent economic and environmental factors, as well as accessibility to affordable natural gas, have shifted this trend. According to a 2013 LCA study on used oil by the California Department of Resources Recycling and Recovery, asphalt plants with bag house filters account for 50 percent of all recycled fuel oil combustors in the State of California, space heaters account for 5 percent, boilers account for 35 percent, and cement kilns account for 10 percent.[129]

Cement production plants have advanced greatly in the past few decades. According to the 2019 U.S. Geological Survey, U.S. production of Portland cement in 2018 increased slightly to 85.4 million tons, and output of masonry cement continued to be stagnant at 2.4 million tons at 98 plants in 34 States.[130] Overall, U.S. cement production continued to be well below the record level of 99 million tons reported in 2005, indicating continued full-time idle status at a few plants, underutilized capacity at many others, production disruptions from plant upgrades, plant closures over the interim, and relatively inexpensive imports in some recent years.[131] Texas, California, Missouri, Florida, and Alabama were, in descending order of production, the five leading cement-producing States and accounted for nearly 50 percent of U.S. production.[132] Fuels such as coal, oil, petroleum coke, and natural gas have been used in traditional kilns.

Cement companies are under pressure from economic and environmental constraints and, as such, are evaluating what extent conventional fuels can be replaced by alternative and waste fuels.[133] As a key material for global construction needs, the cement industry is challenged with conserving raw materials and energy resources. On average, approximately 30 to 40 percent of total cement production costs are energy costs. The substitution of alternative fuels such as waste oil will help reduce costs and provide an economic advantage for participating cement plants. Cement kilns are ideal for disposing of used oil and lubricants, such as motor oils, gear oils, brake fluids, transmission fluids, compressor oils, and refrigeration oils, because the

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[128] Asphalt Pavement Alliance, "The United States has 2.2 million miles of paved roads, and about 93% of them are surfaced with asphalt," *available at* http://www.asphaltroads.org/why-asphalt/economics/.
[129] California Department of Resources Recycling and Recovery, "Critical Review of Used Oil Life Cycle Assessment Study" (August 2013).
[130] U.S. Department of the Interior, U.S. Geological Survey, "Minerals Commodity Summaries 2019" (February 28, 2019), *available at* https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/mcs2019_all.pdf.
[131] *Ibid.*
[132] *Ibid.*
[133] Nickolaos Chatziaras, Constantinos S. Psomopoulos, Nickolas J. Themelis, "Use of waste derived fuels in cement industry: a review," Management of Environmental Quality: An International Journal, Vol. 27 Iss 2 pp. 178–193. (March 14, 2016), *available at* http://dx.doi.org/10.1108/MEQ-01-2015-0012.

temperatures in cement kilns are much higher than other combustion systems, such as incinerators, and ensure high combustion efficiencies.

Burning used oil for thermal use is not limited to land-based industrial applications such as asphalt and cement plants. The marine and shipping industry has burned bunker fuels for decades as a main source of energy. Bunker fuels are graded as A, B, or C and are often blended with a lighter fuel such as diesel as an inexpensive fuel for international cargo shipping. Starting January 1, 2020, the International Maritime Organization (IMO) will require all fuels used in ships contain no more than 0.5 percent sulfur.[134] The cap is a significant reduction from the existing sulfur limit of 3.5 percent and is well below the industry average of 2.7 percent sulfur content.[135] Initially, many ship owners are expected to replace heavy bunker fuel with lower sulfur fuels such as marine gas oil. With the switch, global shipping fuel costs may rise by at least $24 billion in 2020, in part because the cleaner fuels cost more to produce.[136] Used oil collectors and re-refiners are poised to re-refine used motor oil into low sulfur fuels without significant investment.

[134] International Maritime Organization, Frequently Asked Questions: The 2020 global sulphur limit, *available at* http://www.imo.org/en/MediaCentre/HotTopics/GHG/Documents/2020%20sulphur%20limit%20FAQ%202019.pdf.
[135] Maria Gallucci, "At Last, the Shipping Industry Begins Cleaning Up Its Dirty Fuels" Yale Environment 360, (June 28, 2018), *available at* https://e360.yale.edu/features/at-last-the-shipping-industry-begins-cleaning-up-its-dirty-fuels.
[136] Ibid.

VII. Government Role in Used Oil Management

Federal Programs

Federal Environmental Regulations Dealing with Used Oil

The primary Federal-level regulation that applies to used oil was enacted by EPA and is established in Title 40 of the CFR Part 279.[137] EPA's management standards provided in 40 CFR part 279, which are essentially a set of "good housekeeping" requirements for used oil handlers, establish streamlined procedures for notification, testing, labeling, and record keeping. They also establish a flexible approach for tracking offsite shipments that allow used oil handlers to employ standard business practices (e.g., invoices, bills of lading). In addition, 40 CFR Part 279 sets standards for the prevention and cleanup of releases to the environment during used oil storage and transit. An EPA website devoted to answering questions related to 40 CFR Part 279 includes links to all of the State environmental or hazardous waste management agency web pages where individual State regulations associated with used oil are referenced.[138]

40 CFR Part 279 includes nine subparts (A through I):

A. Definitions
B. Applicability
C. Standards for Used Oil Generators
D. Standards for Used Oil Collection Centers and Aggregation Points
E. Standards for Used Oil Transporter and Transfer Facilities
F. Standards for Used Oil Processors and Re-Refiners
G. Standards for Used Oil Burners, who Burn Off-Specification Used Oil for Energy Recovery
H. Standards for Used Oil Fuel Marketers
I. Standards for Use as a Dust Suppressant and Disposal of Used Oil

According to EPA, these management practices establish a structure that minimizes the potential for mismanagement of used oils without being so onerous as to discourage recycling. Used oils that are recycled are not classified as hazardous wastes, primarily because of the possibility that such a characterization might discourage or hinder recycling. However, used oils found to contain PCBs must be managed in accordance with the applicable requirements of the Toxic Substances Control Act (TSCA), and used oils found to have been mixed with hazardous waste must be managed in accordance with the applicable requirements of the Resource Conservation and Recovery Act (RCRA). EPA regulations allow for recycling and burning of used oils for heating purposes as long as the volume is limited to used oil generation activities but prohibit collection of used oil from others for the purpose of space heating on the basis that the volumes

[137] 40 CFR § 279.1 et seq.
[138] U.S. Environmental Protection Agency, *Managing Used Oil: Answers to Frequent Questions for Businesses* (April 29, 2019), *available at* https://www.epa.gov/hw/managing-used-oil-answers-frequent-questions-businesses.

could increase to the point where they have environmentally significant impacts. Mines, military installations, and service station garages where space heaters may be used for seasonal heating are examples of where these regulations would be most applicable. The objective was not to impose a significant burden on small used oil generators who have long standing practices of utilizing used oil as an economical heating fuel.

EPA rules limit the use of used motor oils. Appendix D further details the highlights of key Federal statutes and regulations involving used oil management, including:

- Resource Conservation and Recovery Act (RCRA) Used Oil Management Standards
- Toxic Substances Control Act
- Clean Air Act (CAA) National Emission Standards for Hazardous Air Pollutants (NESHAP)
- Clean Air Act Offsite Waste Rule
- Clean Water Act Centralized Waste Treatment (CWT) Point Source Category
- Spill Prevention Control and Countermeasures (SPCC) plan requirements
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- Emergency Planning and Community Right to Know Act
- Nuclear Regulatory Commission used oil regulations
- Coast Guard used oil regulations dealing with releases of used oil to navigable waters and shipboard management of used oil
- Hazardous Materials Transportation Act (HMTA)

Executive Orders Applicable to Executive Branch Agencies

The Resource Conservation and Recovery Act, Section 6002, included statutory purchasing and waste prevention mandates, which are detailed in Appendix D. Subsequently, EOs have been issued by successive administrations to emphasize the implementation of these mandates with respect to used motor oil and recycled products.

EO 13101, "Greening the Government through Waste Prevention, Recycling, and Federal Acquisition," was enacted on September 14, 1998.[139] In the interest of pollution prevention, this promoted waste management, recycling, and the preferred use of end products made of recycled materials, including lube oils. It specifically required that "agencies shall implement the EPA procurement guidelines for re-refined lube oils and retread tires." Additional information on EPA procurement guidelines can be found on the EPA website.[140]

[139] Executive Order 13101, "Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition" (Sept. 14, 1998), *available at* https://www.epa.gov/greenerproducts/executive-order-13101-greening-government-through-waste-prevention-recycling-and.
[140] U.S. Environmental Protection Agency, "EPA Comprehensive Procurement Guideline (CPG) Program," *available at* https://www.epa.gov/smm/comprehensive-procurement-guideline-cpg-program.

EO 13149, "Greening the Government through Federal Fleet and Transportation Efficiency," was enacted on April 21, 2000.[141] It specifically required that "no Federal agency shall purchase, sell, or arrange for the purchase of virgin petroleum motor vehicle lube oils when re-refined motor vehicle lube oils are reasonably available and meet the vehicle manufacturer's recommended performance standards."

Both of these EOs were revoked by EO 13423, "Strengthening Federal Environmental, Energy, and Transportation Management,"[142] which was enacted January 26, 2007. This EO was subsequently revoked by EO 13693, which was enacted March 19, 2015, and titled "Planning for Federal Sustainability in the Next Decade."[143] Neither of these two EOs specifically mentioned re-refined motor vehicle lube oils or specifically direct Federal Government agencies to preferentially procure lubricants made from re-refined used oil. However, EO 13693 directed Federal Government agencies "promote sustainable acquisition and procurement by ensuring that each of the following environmental performance and sustainability factors are included to the maximum extent practicable for all applicable procurements in the planning, award, and execution phases of the acquisition by … meeting statutory mandates that require purchase preference for … recycled content products designated by EPA." EPA's Consolidated Recovered Materials Advisory Notice (RMAN) for the Comprehensive Procurement Guideline (CPG) states that "EPA recommends that procuring agencies set their minimum re-refined oil content standard at the highest level of re-refined oil that they determine meets the statutory requirements of RCRA Section 6002(c)(1), but no lower than 25 percent re-refined oil."[144]

EO 13693 was subsequently revoked by EO 13834, "Efficient Federal Operations," which was signed on May 17, 2018, and directs Federal agencies to manage their buildings, vehicles, and overall operations to optimize energy and environmental performance, reduce waste, and cut costs.[145] It also directs the head of each agency to meet the goals in the EO, which are based on statutory requirements and specifically to implement waste prevention and recycling measures and comply with all Federal requirements with regard to solid, hazardous and toxic wastes. In addition, agencies are directed to acquire, use and dispose of products and services in accordance with statutory mandates for purchasing preference, Federal Acquisition Regulation requirements, and other applicable Federal procurement policies. The EO 13834 Implementing Instructions specifically state agencies must give purchasing preference to products that meet minimum requirements for recycled content as identified by EPA in the Comprehensive Procurement Guidelines (CPG) which includes re-refined lubricating oil. This EO affirms that it is the policy

[141] Executive Order 13149, "Greening the Government through Federal Fleet and Transportation Efficiency" (Apr. 21, 2000), *available at* https://www.archives.gov/federal-register/executive-orders/2000.html#13149.

[142] Executive Order 13423, "Strengthening Federal Environmental, Energy, and Transportation Management" (Jan. 24, 2007), *available at* https://www.archives.gov/federal-register/executive-orders/2007.html.

[143] Executive Order 13693, "Planning for Federal Sustainability in the Next Decade" (March 19, 2015), *available at* https://www.epa.gov/greeningepa/executive-order-13693-planning-federal-sustainability-next-decade.

[144] U.S. Environmental Protection Agency, Consolidated RMAN for the CPG, (compiled 1997, revised 2007), *available at* https://www.epa.gov/sites/production/files/2016-03/documents/consolrman.pdf.

[145] Executive Order 13834, "Efficient Federal Operations" (May 22, 2018), *available at* https://www.federalregister.gov/documents/2018/05/22/2018-11101/efficient-federal-operations.

of the United States that agencies meet energy and environmental performance statutory requirements in a manner that increases efficiency, optimizes performance, eliminates unnecessary use of resources, and protects the environment.[146]

Prior use demonstrates that these products can be used by Federal agencies without quality concerns. Companies that market to the Federal Government can advertise those relationships to promote additional sales and demonstrate the technical viability of the products.

State Programs

EPA encouraged all States to adopt the practices outlined in 40 CFR Part 279 by developing statewide programs to manage used oils. Most States have adopted the 40 CFR Part 279 practices with some additional modifications unique to their needs. Some States have instituted their own regulations similar to 40 CFR Part 279. Many States have implemented proactive local programs for the collection of used oils, and a few provide funding to motivate progress at the county or municipal level.

In 1997, API conducted an extensive study on used oil management and surveyed recycling programs State-by-State. It showed that efforts to collect used motor oil were not uniformly distributed across the country. Over the subsequent decade, many States have made progress in supporting used oil collection and management. However, there are still areas of the country where used oil recycling remains challenging.

Elements of State Programs

In preparation of this report, a survey was taken of State websites for information on used oil collection practices and programs (see the table provided in Appendix F). Some features of these State practices that have evolved since the previous report include the following:

- Only one State, California, collects taxes on lube oil sales and channels those funds back to used oil collection facilities. The 1997 API survey found that nine States did this.
- All 50 States and Washington, D.C., have adopted regulations that pertain to the handling of used oils (collection, contamination, containers specifics, etc.). Thirty-six States have adopted the 40 CFR Part 279 recommended management practices with some State-specific modifications, while 16 States have promulgated their own regulations, often quite similar to 40 CFR Part 279. Accordingly, all 50 States and Washington, D.C., have rules for handling of used oil and reporting on volumes of used oil collected.
- Forty-nine States (excluding North Dakota) and Washington, D.C., have rules for disposal of used oil filters. The 1997 API survey found only three States that banned oil filters from landfills. However, only two States appear to have local programs for the recycling of used

[146] *Id.*

oil filters (California and New Hampshire). In the 1997 API survey, there were eight State programs.

- Twenty-two States have enacted purchasing program preferences for recycled products of all kinds. Of these, six States specifically note lubricants derived from used oils as a preferred purchasing option (California, Hawaii, Missouri, Oklahoma, Pennsylvania, and Texas).
- All 50 States have used oil collection locations operated by State or local entities. Only five States operated collection centers funded directly by the State (California, Delaware, Illinois, Indiana, and Maryland). In all other States and Washington, D.C., the collection centers are operated under county or local (town, township, city, etc.) auspices. Some States provide grants for local organizations to operate collection centers. The API 1997 survey showed that only 32 States had collection centers.
- Thirty-six States have locally organized intermittent or seasonal curbside hazardous waste collection events. The API 1997 survey found only 11 curbside collection programs.
- All 50 States and Washington, D.C., require retailer collection of used oil. The API 1997 survey noted only 42 States where lubricant retailer collection was indicated.
- Thirty States have online searchable databases (or in some cases, printable lists) of collection center and retailer locations where used oil can be recycled. The other States generally direct individuals interested in recycling used oil to call their city or country office. The website *Earth911* has a database of used oil recycling collection locations (retailer, city, county, and State locations) searchable by zip code.[147]

Considering the broad range of collection programs that exist across the United States, it is difficult to identify one solution as a model that could be used across the country. This is a complicating factor when considering specific steps that might be taken at the Federal level to further improve used oil collections nationwide.

State Legislation

In preparation of this report, an Internet search was conducted of State websites for information on used oil management legislation. The results of this search determined that all 50 States and Washington, D.C., have used oil management legislation. Most States' regulations are based on 40 CFR Part 279 guidance. Several States have not adopted Federal used oil management rules but have State regulations that are stricter. These standards cover all segments of the used oil recycling enterprise and apply to generators, transporters, marketers, processors/re-refiners, and burners of used oil. In addition, many States have added additional requirements specific to their jurisdiction. For example, some States require:

- Used oil collection centers to register with the State;

[147] Earth911, "Earth911 Recycling Search," *available at* https://search.earth911.com/.

- Used oil collection centers to submit an annual report or in some cases quarterly reports;
- Used oil transporters to comply with specific Federal hazardous material regulations;
- Used oil handlers to follow specific procedures in response to a release of a used oil;
- Used oil handlers to register with the State's Department for Environmental Protection or similar State regulator;
- Certification of used oil burned for energy recovery;
- Labeling of tanks holding on-specification used oil;
- Inspections and used oil testing by the State's Department of Environmental Quality;
- Reporting by processors/re-refiners of used oil;
- Notification of specific State regulatory agencies of used oil handling activities or emergencies; and
- Adherence to specific rules regarding:
  - The status of used oil containers (e.g., that they be kept closed);
  - Specific signage requirements for sellers of lubricating oil and vehicle oil filters;
  - Special shipping manifest regulations;
  - Approval of used oil transfer before commencing operations;
  - The storage and mixing of used oil and hazardous wastes;
  - Specific disposal prohibitions with specified penalties for non-compliance;
  - Specific rules regarding mixtures of used diesel engine crankcase oil and diesel fuel;
  - Total halogen content of on-specification used oil;
  - Used oil generators using space heaters;
  - Air permits for burners burning off-specification used oil for energy recovery; and
  - Utilization of used oil as a dust suppressant on roads.

The States may also have additional State rules in connection with definitions of terms (e.g., what constitutes "used oil," forms, prohibitions, recordkeeping, permitting, and financial assurance requirements). As an example, Appendix E contains the applicable California legislation dealing with the management of used oils.

Local Programs

Many local communities, cities, towns, townships, and counties fund and manage used oil collection centers as stand-alone drop-off points or as one of several recycling options within a larger recycling location. Some local jurisdictions also hold intermittent collection events where DIYs can bring used oil to a publicized location for collection.

Some communities also offer "curbside" collection programs that allow consumers to put their oil out on the curb for collection, as they already do with their other recycling and trash. While this approach is more convenient for the DIY people, it requires a collector to come and collect the oil and, depending on the number of participants, can be fairly inefficient. Curbside collection programs are implemented by municipal or private waste or recycling haulers.

Other

EPA's diesel fuel and fuel additives regulations covering the diesel fuel ban from blending used motor oil into diesel fuel for model year 2007 or later diesel motor vehicles, model year 2011 or later, and non-road diesel engines (not including locomotive or marine diesel engines, unless approved through certification by the engine manufacturer). Effectively, the practice of mixing used oil into diesel fuel by operators would be phased out.

VIII. Environmental and Energy Impacts of Re-refining Used Oil

Part of the scope of the 2006 DOE report was to evaluate the energy and environmental impacts of used oil waste management.[148] Used oil can either be collected or disposed. Collected oil is preferred over disposed oil because collection can recover a valuable resource and avoid potential drinking water and soil contamination. Collected used oil can be managed in two ways: (1) re-refining into base stocks or (2) processed into a fuel for combustion. These two strategies will be referred to as re-refining and combustion, respectively. Assessing whether individual waste management strategies have overall beneficial energy and environmental impacts, as well as which of the strategies is preferred, can influence State and Federal policy and guide future research and investments.

LCA is a framework that assesses the comprehensive environmental impacts of a product or service over its lifetime.[149] The life cycle of a product begins with raw material acquisition, includes production and use of a product, and ends with waste disposal and decommissioning activities. LCA can be combined with other analytical approaches to identify trade-offs between the environmental and economic performance of systems.

The purpose of this section is to review the LCAs on used oil waste management published since 2006 to determine if there exists a waste management disposition that has more favorable energy and environmental impacts. The LCA categories examined in this section are listed in Appendix G, Table G-1. This rest of this section will: (1) list the major LCAs published since 2006 that are relevant to the U.S. used oil industry; (2) compare the energy and environmental impacts of re-refining and refining virgin oil from crude; (3) compare the energy and environmental impacts for re-refining and combustion of used oils; and (4) identify limitations, brainstorm future work, and conclude. This section does not compare energy and environmental impacts of used oil combustion to other fuels due to a lack of LCA data that explicitly compare those two processes.

Overall, the LCA literature on environmental and energy impacts suggests that producing products through re-refining of used oil or from virgin oil has tradeoffs and neither primary waste management strategy dominates the other in any of the major LCA impact categories. Further, there are significant uncertainties in the underlying data and method differences in these LCAs, so that it is difficult to draw a decisive conclusion about the favorability of one waste management strategy over another. Future work should focus on collecting data that fully captures the mass flows in the U.S. used oil management system, formally harmonizing the existing LCA studies to compare studies with different analytical approaches and conducting a separate study that includes the entire contiguous United States.

[148] U.S. Department of Energy Office of Fossil Energy, Used Oil Re-Refining Study to Address Energy Policy Act of 2005 Section 1838 (2006).
[149] "ISO 14044:2006: Environmental management – Life cycle assessment – Requirements and guidelines" (2006).

Studies Examined

Since DOE's 2006 study on used oil re-refining to address the Energy Policy Act of 2005, several LCAs have been published on the environmental and energy impacts of used oil re-refining and combustion. Eight studies, along with their scope and description, are listed in Appendix G, Table G-2. The eight studies vary in assumptions, system boundaries, input data, modeling technique, impact criteria, and geographic representativeness. This section highlights the four studies, listed in Table 13, that are most reflective of current U.S. technologies and industry applications.

Table 13. List of LCA Studies on Used Oil Combustion and/or Re-Refining Used in This Environmental Impact Assessment

Author (Organization)	Year	Location	Impact Criteria	Functional Unit	Synopsis
Abdalla and Fehrenbach[150] (IFEU)	2018	Germany	Acidification, carcinogenic risk, eutrophication, fine particulates, global warming potential (GWP), resource depletion	1 metric ton of used oil	Re-refining performs better than combustion of used oils, but combustion pathway is not reflective of U.S. technologies.
Collins et al.[151] (American Petroleum Institute)	2017	California	Abiotic depletion, acidification, ecotoxicity, eutrophication, fossil fuel depletion, GWP, human health, human toxicity (carcinogenic and non-carcinogenic), ozone depletion, smog air	All oil flows in California in 2010 (435,000 metric tons)	Combustion of used oils is comparable to re-refining, especially if pollution controls are installed on combustion sources.
Geyer et al. [152] (CalRecycle)	2013	California	Acidification, ecotoxicity, eutrophication, global warming potential (GWP), human health cancer and non-cancer potential, human health criteria air pollutant.	All oil flows in California in 2010 (435,000 metric tons)	Increasing used oil collections is good. Waste management strategies have impact tradeoffs.
Grice et al. [153] (Safety-Kleen)	2014	Contiguous United States	GWP	1 gallon of re-refined used oil	Re-refined used oil shows lower GWP impacts than producing virgin oil from crude in all analyses.

[150] N. Abdalla and H. Fehrenbach, "LCA for regeneration of waste oil to base oil," 2018.
[151] M. Collins, K. Schiebel, and P. Dyke, "Life Cycle Assessment of Used Oil Management," 2017.
[152] R. Geyer, B. Kuczenski, A. Henderson, and T. Zink, "Life Cycle Assessment of Used Oil Management in California Pursuant to Senate Bill 546 (Lowenthal)," 2013.
[153] L. N. Grice, C. E. Nobel, L. Longshore, R. Huntley, and A. L. DeVierno, "Life cycle carbon footprint of re-refined versus base oil that is not re-refined," *ACS Sustain. Chem. Eng.*, vol. 2, no. 2, pp. 158–164, (2014).

Used Oil Re-refining and Crude Oil Refining

It is important to analyze the energy and environmental impacts of recycling a fuel versus generating fuel from scratch, while considering market variability within the lubricants and base oils industries. Depending on the tradeoffs between energy and environment costs and benefits, re-refining used oil compared to an equivalent oil or lubricant product generated from virgin feedstock materials. Independent of LCAs, local market needs may not always pursue re-refining as the preferred waste management strategy. In considering this review of pertinent LCAs, among studies listed in Table 13, Abdalla and Fehrenbach compare the energy impacts, and Grice et al. compares global warming potential between re-refining and refining. Of note, there are no studies that directly compare the energy and environmental impacts of used oil combustion against a substitutable fuel used in U.S. industry, such as marine distillate oil.

Abdalla and Fehrenbach is an LCA produced by the Institut für Energie- und Umweltforschung Heidelberg (known as the IFEU and translated to Institute for Energy and Environmental Research). Based on the analysis, the re-refining process nets energy benefits on average 50 gigajoule (GJ)/metric ton (6.5 million Btu/bbl) compared to the mixed Group I and IV base oils process.[154] Even the minimum case, which incorporates impacts from the worst-performing re-refining processing techniques, re-refining nets 47 GJ/metric ton (6.1 million Btu/bbl). Regardless of whether the re-refining technique is used in the United States or not, re-refining processes have less energy intensity than processes that refine virgin oils from crude.

A key distinction in this work compared to other LCAs is how Abdallah and Fehrenbach approximate the Group II and Group III base oils by estimating the energy impacts of a mix of Group I and Group IV oils with a viscosity similar to the Group II / III oils. This approximation is not necessarily an accurate substitution for actual Group II and III base stocks and may overestimate the energy impacts of refining virgin oil from crude. Within this review, it is noted that operational differences in Group II and Group III base stock production processes can be cheaper and more energy efficient than what is modeled. While these are areas that could be further assessed in potential, future LCA work, it is not expected that the directionality of the comparison would change.

Comparing against previous literature, the 2006 DOE report stated that the estimated energy impacts of re-refining are about twice as favorable as refining virgin oil from crude oil.[155] Those results are based on industry and literature data reported in 1995 and not based on an empirical LCA study. The order of magnitude results reported by Abdalla and Fehrenbach are the most optimistic framing for the used oil re-refining value chain. They assume used oil is a free input, excluding upstream impacts caused by manufacturing and using oil. If used oil is disposed of

[154] N. Abdalla and H. Fehrenbach, "LCA for regeneration of waste oil to base oil," (2018).
[155] U.S. Department of Energy Office of Fossil Energy, Used Oil Re-Refining Study to Address Energy Policy Act of 2005 Section 1838 (2006).

directly to landfill, then this assumption is appropriate to make because the used oil offered zero utility to any other process. In a more practical context, used oil is produced by upstream processes, which can be incorporated in the LCA impacts. Used oil is also sold to and used by downstream processes, such as combustion, suggesting that proper accounting should also incorporate the displaced products. The actual energy savings will depend on how much of the used oil will be tied up in other upstream and downstream processes. Expanding LCA across the wider value chain would improve component energy assessments and systems evaluation.

PD Consulting (on behalf of API) examined some of the wider value chain implications. In response to DOE feedback, PD Consulting authored two documents commenting on the energy balance of used oil management. In this energy balance, PD Consulting uses existing data from Collins et al., Geyer et al., and Abdalla and Fehrenbach to estimate the electricity and energy required to re-refine base stock from used oil from five different re-refining techniques and refine base stock from crude oil. The goal is to compare whether recycling used oil would require less energy and electricity than from crude oil. The results are reproduced in Table 14, and they show that re-refining does not have ubiquitous energy and electricity benefits. In some situations, re-refining might require either more electricity or more heat, but not both, than refining virgin oil from crude. The electricity and energy impacts will need to be traced upstream and unified into a single energy unit before concluding whether certain re-refining techniques perform better or worse energetically than refining virgin oil from crude. The results in Table 14 suggest that further study might be needed on this energy comparison.

Grice et al. compares the global warming potential of Safety-Kleen Systems' re-refined used oil against equivalent virgin products developed from crude oil.[156] This analysis incorporates processes used in U.S. industrial applications and is illustrative of current domestic systems. Grice et al. assumes the re-refining system yield is 86 percent, which is based on Safety-Kleen's production values. They attempt to re-collect and reuse this oil as many times as possible and, in this work, a gallon of base stock can be re-refined and reused into 7.14 gallons of use. They also assume that virgin base stock is produced, used once, and disposed (with and without energy recovery).

Grice et al. estimates the re-refining of used oil and refining of crude oil has a GWP of 2.5 kg CO_2-eq/gallon base stock and 13.3 kg CO_2-eq/gallon base stock, respectively. The carbon footprint of re-refining is 81 percent less than the production of fresh virgin oil from base stocks. The largest contributors to the carbon footprint of refining crude oil are from the base stock production and end-of-life processes. Grice et al. attributes these differences to the energy and material resources in the recycled process compared to producing virgin oil from scratch. Because reused oil can spread the impact across multiple lifetime uses or reduce disposal impacts, the carbon footprint of re-refining processes in the production and end-use stages are 82 percent less than refining crude oil. If GWP impacts correlate with energy use, the GWP savings from re-refining used oil is not surprising based on the results from the energy comparison from

[156] L. N. Grice, C. E. Nobel, L. Longshore, R. Huntley, and A. L. DeVierno, "Life cycle carbon footprint of re-refined versus base oil that is not re-refined," *ACS Sustain. Chem. Eng.*, vol. 2, no. 2, pp. 158–164, (2014).

Abdalla and Fehrenbach. Although not shown here, Grice et al. finds that re-refining used oil has a lower GWP than refining crude oil in all sensitivity analyses. The sensitivity analyses include displaced fuels, number of re-refining re-uses, and heat content of used oils.

Table 14. Energy Balance of Re-Refining Used Oil Compared to Production from Crude

Technique / Process	Energy Required *		Displaced Production –Energy Credit for All Outputs *		Difference Compared to Primary Production (U.S. data)	
	Electricity Megajoule (MJ)	Heat MJ	Electricity MJ	Heat MJ	Electricity MJ	Heat MJ
Re-refining Process 1	0.93	2.1	0.50	3.53	-0.43	1.42
Re-refining Process 2	0.24	4.9	0.45	3.12	0.22	-1.78
Re-refining Process 3	0.13	2.4	0.40	2.65	0.27	0.26
Re-refining Process 4	0.30	3.2	0.48	3.36	0.18	0.13
Re-refining Process 5	0.24	3.8	0.47	3.28	0.24	-0.55

*Per kg of used oil processed. Yellow highlight indicates that the process in the row uses *more* energy than the primary process. Data is reproduced from PD Consulting.

A key sensitivity in the Grice et al. analysis is the reliability of re-refining and reusing a gallon of base stock into 7.14 gallons of use. This assumption is likely optimistic since used oil can only be reused indefinitely if re-refining was the only application for collected oil. In practice, a fraction of collected used oil is combusted. When a gallon of used oil is re-refined, reused, and then recollected, a fraction of the recollected used oil is combusted and removed from the re-refining supply chain. The Grice et al. analysis does not capture combustion in its system yield and reuse oil lifetime collection. Therefore, generating 7.14 gallons of re-refined oil from the continuous reuse of a gallon of used oil is ideal, and in practice, the amount of re-refined oil generated will be lower. Investigating the true yield of re-refined oil from a gallon of used oil may be worthwhile, even if the directionality of the comparison is unlikely to change. While uncertainties exist in the underlying data, Grice et al. analysis suggests re-refining appears to be more environmentally and energetically favorable than refining virgin oil from crude.[157]

[157] L. N. Grice, C. E. Nobel, L. Longshore, R. Huntley, and A. L. DeVierno, "Life cycle carbon footprint of re-refined versus base oil that is not re-refined," *ACS Sustain. Chem. Eng.*, vol. 2, no. 2, pp. 158–164 (2014).

Used Oil Re-refining and Combustion

From Table 13, three studies compare the energy and environmental impacts of used oil re-refining to combustion. Those three studies are Abdalla and Fehrenbach, Geyer et al., and Collins et al. They will be covered individually.

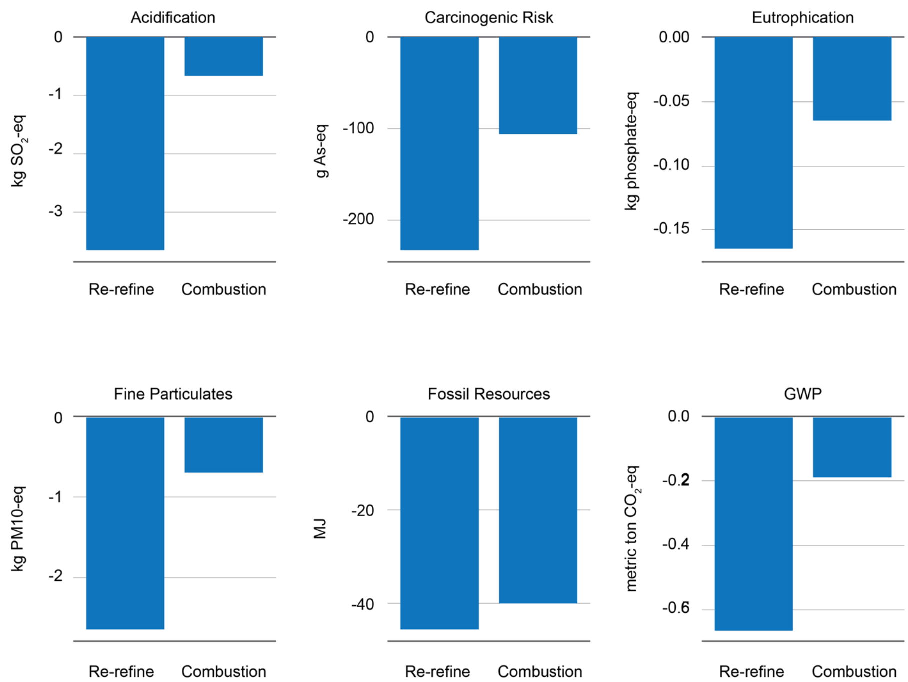
Abdalla and Fehrenbach, covered in the previous subsection, also estimate the LCA impacts of four different re-refining processes against a combustion product, processed fuel oil. The four re-refining processes are European techniques used in France, Germany, and Greece, but are close enough to U.S. industry practices that they serve as a reasonable proxy. Processed fuel oil on the other hand is a uniquely UK process that has greater resource requirements than U.S.-based combustion processes. In this LCA, managed used oil displaces an existing process. Re-refining displaces base stock produced from scratch, and combustion substitutes light fuel oil.

Figure 25 shows a selection of the impact criteria calculated by Abdalla and Fehrenbach for a functional unit of 1 metric ton of used oil. The re-refining impacts are averaged across the four process methods. Overall, Abdalla and Fehrenbach show that re-refining has more favorable impacts than combustion for all LCA impact criteria. This result is robust based on their sensitivity analysis, which is not shown here. Ultimately, they conclude that re-refining is the strictly better waste management option. While this work is illuminating, the combustion process modeled in this LCA does not model U.S. industry processes and may be overestimating the energy and environmental impacts of combustion. Abdalla and Fehrenbach communicates that re-refining and combustion are more energetically and environmentally favorable than their substituted process, and in the European market, re-refining is preferable to combustion. Future work could build off this model by modeling combustion processes that are used in the United States. While re-refining will outperform combustion on some LCA criteria, it is unclear if that will hold true for all impact categories.

Geyer et al. is a report commissioned by CalRecycle and the California Department of Resources, Recycling, and Recovery, as pursuant to California Senate Bill 546. The goals of the study are to quantify the environmental impacts of managing oil, to model sensitivities based on potential developments in California, and to provide results that can assist California decision-makers with increasing collection and managing used oil. A team from the University of California, Santa Barbara performed the bulk of the modeling work, and a separate committee reviewed the LCA for its scientific robustness. Multiple stakeholder groups ranging from government, industry, and academia provided input.

Geyer et al. created three "extreme" waste management scenarios that are intended to highlight differences in environmental impacts between the routes. In each extreme scenario, all used oils are collected and fed as the raw material into each one of those three dispositions. The three scenarios are named after the primary (but not exclusive) product that they produce, and all used oil is collected and reprocessed into one of three disposition routes: RFO and MDO are fuel petroleum products involved in the combustion-based aspects of used oil management strategies, and re-refined base oil (RRBO) is a lubricant petroleum product involved in the re-refining aspect of a used oil management strategy. The functional unit of the study is 435,000 metric tons, which is the estimated total used oil generated in California in 2010. The system boundary includes the entire used oil system. Geyer et al. assumes that California requires a set amount of heat and base oil. In these three scenarios, they assume all used oil is collected displacing existing products and assume the rest of the oil and heat demand is met through other fuels.

Figure 25. Summary Results* from Abdalla and Fehrenbach for a Selection of LCA Impact Criteria [158]



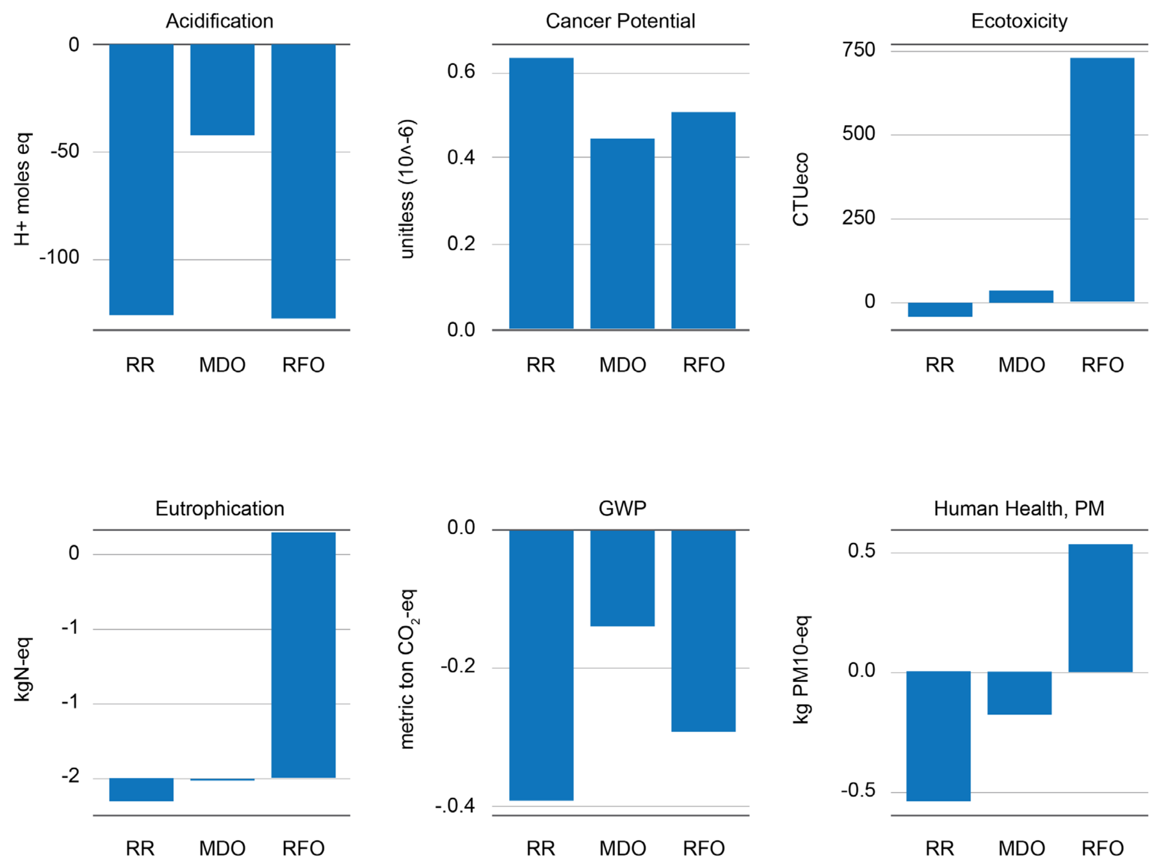
*Results are reproduced from Abdalla and Fehrenbach and normalized to a metric ton of used oil.

Figure 26 shows the results from Geyer et al. for a selection of the LCA impacts, focusing more on the global warming potential and human health impacts. Geyer et al. does not cover energy impacts. The impacts in Figure 26 are net impacts that sum the impacts of the waste management system and subtract them against the processes they displace. Hence, the more negative or less positive the impacts, the better.

Based on Figure 26, re-refining has the lowest ecotoxicity, eutrophication, GWP, and human health impacts. However, one of the two combustion strategies has lower impacts for the other three categories. This result implies that tradeoffs exist between the two strategies and within the strategy. For example, converting used oil to MDO is better than RFO for human health but unfavorable for climate change.

158 N. Abdalla and H. Fehrenbach, "LCA for regeneration of waste oil to base oil," 2018.

Figure 26. Summary Results* from Geyer et al. for a Selection of LCA Impact Criteria [159]



*Results are reproduced from Geyer et al. and normalized to a metric ton of used oil.

Collins et al. is an LCA on used oil waste management with a focus on California. The study is an extension of Geyer et al. and was performed by Environmental Resources Management, Ltd. for API, with CalRecycle, the University of California, Santa Barbara, and the National Oil Recyclers Association as stakeholders. This study uses a functional unit of 435,000 metric tons of used oil, which represents all used oil generated in California in 2010.

Similar to Geyer et al., Collins et al. created "extreme" scenarios based on the dispositions used in Geyer et al., and the study included VGO as a fourth disposition. VGO is an intermediate product that can be involved in either fuel or lubricant end uses. Since each of these dispositions produce a different mix of fuel and lubricant petroleum products, these scenarios include an additional balancing step where virgin refineries make up product shortfalls, such that the final quantity of fuel and lubricant products is identical for each scenario.

[159] R. Geyer, B. Kuczenski, A. Henderson, and T. Zink, "Life Cycle Assessment of Used Oil Management in California Pursuant to Senate Bill 546 (Lowenthal)," 2013.

There are also other elements of the Collins et al. study that are not yet found in other used oil LCA, including quantifying the environmental impacts of uncollected used oil, evaluating the impacts of a broad range of marginal fuels (natural gas, coal, and a series of liquid fuels), analyzing the impacts of differing levels of pollution control (particularly on RFO combustion), and tracking contaminants, such as zinc, across the management system.

Figure 27 shows the LCA results from the four extreme scenarios for 6 of the 12 LCA impact criteria. The results are normalized to a metric ton of used oil. Overall, even based on a subset of the LCA impacts, none of the scenarios stand out as the ideal waste management strategy. RRBO is not strictly worse or better than the VGO or fuel product focused scenarios for any of the impact criteria. For the two resource/energy-based criteria—abiotic depletion and fossil fuels—RRBO outperforms MDO but is more energy intensive than RFO and VGO. For GWP, RRBO and RFO have the lowest and essentially identical greenhouse gas impacts.

These results are congruent with the conclusions of Collins et al., which states "no single disposition shows consistently lower impacts under all conditions, with greater benefits generally flowing from increasing collection, rather than from changing disposition."[160] While Collins et al. has not been published in a peer-reviewed journal, the study is vetted by a separate review panel per ISO 14040 and received input from multiple stakeholders, including government, industry, and academia. The study captures the entire used oil waste management system in California and displaces the products generated in each scenario.

Further work can build off the framework established by Collins et al. A future LCA can also build upon Collins et al., incorporating a mix of pathways that are reflective of future U.S. industry trends, especially if the quantity of used oil and collected used oil changes. It is unlikely that used oil will be processed in a single disposition as was done in this LCA for illustration purposes. The actual environmental impacts will be a weighted average of the RFO, RRBO, MDO, and VGO scenarios, which was covered in Collins et al. under a baseline, all-used-oil-collected scenario. In this baseline scenario, they assume 55.1 percent, 11.4 percent, and 24.9 percent of used oil goes to MDO, RFO, and RRBO, respectively. Given that there are tradeoffs with each used oil disposition, understanding the ideal mix of used oil dispositions that minimizes impacts may be worthwhile.

Future Data Analysis Guidelines

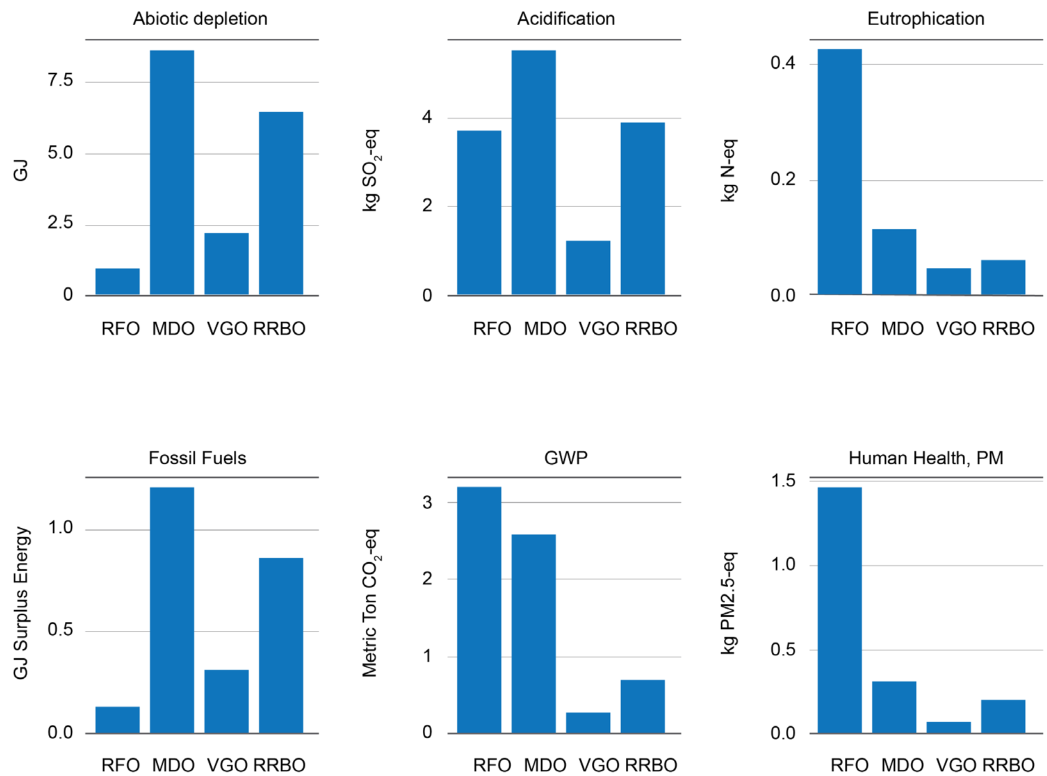
Limitations

This section compares the energy and environmental impacts of creating virgin oil from base stock, re-refining used oil, and combusting used oil based on results from LCAs. The discussion explores whether one alternative performed better than another by assessing whether studies reported that one waste management strategy consistently outperformed the other. These

[160] M. Collins, K. Schiebel, and P. Dyke, "Life Cycle Assessment of Used Oil Management" (2017).

comparisons do not suggest that any alternative would directly incur some quantitative amount of benefits over the other alternative. The type of assessment done in this section is qualitative in nature.

Figure 27. Summary Results* from Collins et al. for a Selection of LCA Impact Criteria [161]



*Results are reproduced from Collins et al. and normalized to a metric ton of used oil

A quantitative assessment would require a formal harmonization assessment, such as the one performed by DOE's National Renewable Energy Laboratory (NREL) on the life cycle of electricity generation.[162] Harmonization allows an LCA practitioner to resolve all the various methodological differences across different LCAs, including system boundaries, impact assessment methods, displaced fuels, and emission factors. Harmonization can help reduce the uncertainty observed across the LCAs, though uncertainty is inherent to any large-scale quantitative assessments, where not all inputs are systematically measured, as exemplified in the NREL harmonization attempt.[163]

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[161] M. Collins, K. Schiebel, and P. Dyke, "Life Cycle Assessment of Used Oil Management" (2017).
[162] G. Heath, "Life Cycle Assessment Harmonization," *National Renewable Energy Laboratory*. [Online]. *available at*: https://www.nrel.gov/analysis/life-cycle-assessment.html. [Accessed: 10-Feb-2019].
[163] *Ibid.*

Analysis

The comparison of the energy and environmental impacts of creating virgin base stock from crude oil, re-refining used oil, and combusting used oil based on results from LCAs suggests that re-refining used oils has a lesser energy and environmental impact than producing virgin oils from base stocks. In addition, though only two studies delve into this comparison, both show that re-refining used oil has less of an energy and environmental footprint than refining virgin oil from crude. However, these studies do not capture upstream impacts. If upstream impacts are incorporated, then the analysis will be less favorable for re-refining used oil.

Despite uncertainty and variability, re-refining used oils tends to have less GWP and eutrophication impacts than combustion of used oils, but results are mixed for energy depletion, human health toxicity, and acidification. Because results cannot be generalized across the United States, any infrastructure investment or policy promoting waste oil management will need to be assessed on a case-by-case basis. Further, the literature has diverging results about which recycling pathway is more favorable. The environmental and energy impacts of used oil combustion are dependent on the end use of the converted fuel, where some end uses perform better than re-refining. Understanding the common end uses and mixes of end uses of used oil combustion is necessary to properly quantify the energy and environmental benefits of different waste management strategies. More harmonization efforts and U.S.-centric LCAs can go a long way toward more accurately quantifying benefits and reconciling the conflicting results observed in the literature.

Future Work

Future work in the used oils LCA space will take two directions. The first is to perform a formal harmonization assessment as alluded to in the previous section. The second is to commission a new and separate LCA that accounts for the entire U.S. used oil system. U.S. - focused studies have either taken place in California (Collins et al. and Geyer et al.) or show a limited set of impacts criteria (Grice et al.). A more holistic study of the U.S. system can affirm whether results observed in California can be extrapolated to the rest of the country. Future work can also properly account for all the intricacies of the U.S. system, such as what fuels are displaced, what the mix of combustion oils would be, what supply and demand constraints are in place, and how much of the impacts caused by base oil production should be attributed to used oil. Ideally, an updated LCA would include the demand for heating energy and virgin oil and maintain that demand regardless of what is displaced. Closing data gaps in the U.S. used oil supply chain would also assist any future LCA efforts.

IX. Used Oil Economics

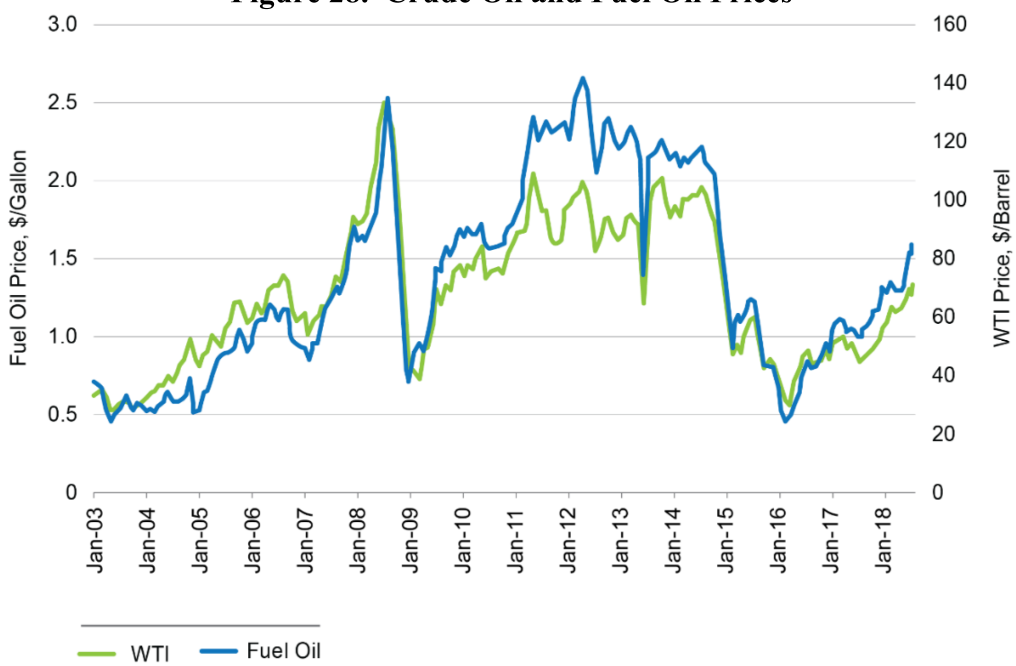
The purpose of this section is to provide an overview of the fundamental economics that drive the used oil and re-refining businesses and to highlight the significant market risks involved. Fuel oil market price is one of the key determinants in the used oil business because of three factors:

I. Fuel oil price sets the basis for used oil sales to industrial consumers that burn the used oil for heating purposes in their manufacturing processes.
II. Fuel oil prices set the accounting basis for re-refiner feedstock costs, thus directly impacting their profitability.
III. Fuel oil market prices indirectly impact consumers; when fuel oil prices are high, DIFM operators can sell their used oil to collectors and generate revenue from those sales, whereas when fuel oil prices are low, DIFM operators may have to pay collectors to have their used oil picked up for recycling, and as a result, they may pass on those added costs to consumers.

Price Correlations among Fuels Options

As shown in Figure 28, there is a strong relationship between crude oil and fuel prices. This chart shows crude oil prices in green and fuel oil market prices in blue on a monthly average basis over a 15-year basis. On this chart, the market price of fuel oil in the U.S. Gulf Coast market is compared to WTI, the most widely traded crude oil in the United States.

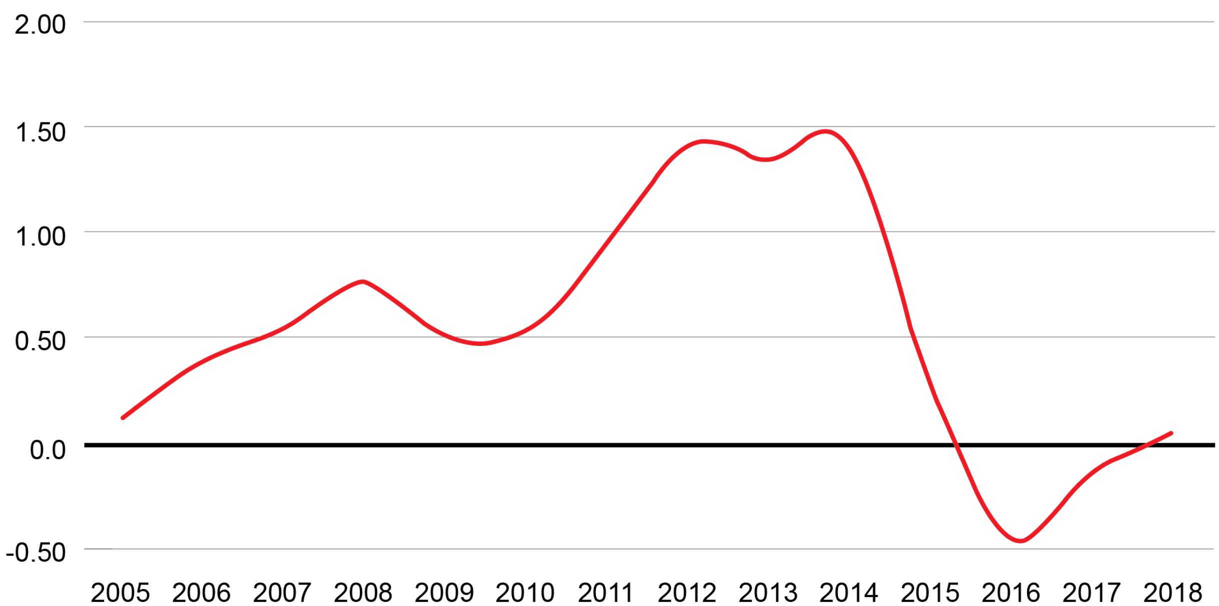
Figure 28. Crude Oil and Fuel Oil Prices



Source: Energy Information Administration

Over the last 15 years, fuel oil prices have generally been sufficiently high that used oil collectors pay for the used motor oil that they pickup from DIFM operators. However, fuel oil prices came under significant pressure during the financial crisis in 2008/2009 and market uncertainties in 2015/2016. As shown in Figure 29, used motor oil prices turned negative in 2016 in reaction to low fuel oil prices. During this period, many collectors had to charge fees to the DIFM operators for their recycling services to offset the loss in revenue from used oil sales whose prices were tied to fuel oil prices. This put financial pressure on all segments of used oil generators, including DIFM operators, dealerships, garages, and municipal recycling operations.

Figure 29. Generator Used Motor Oil Prices ($/Gallon)

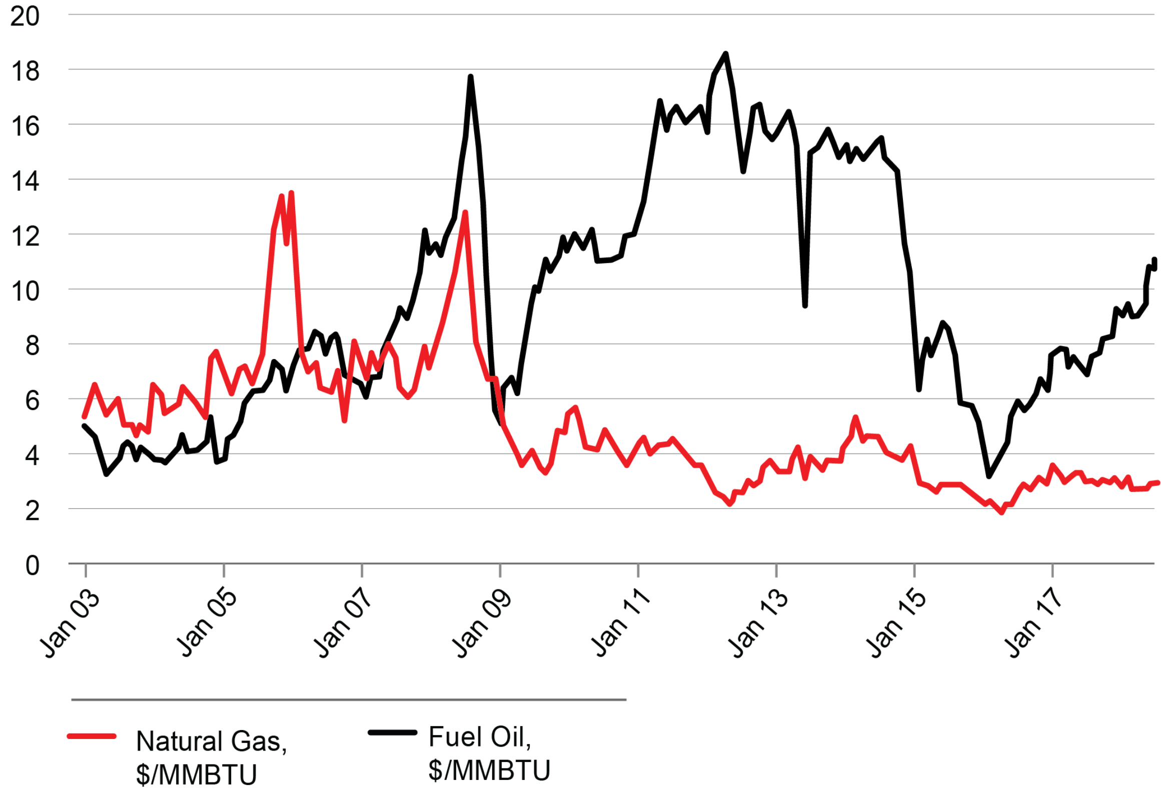


Source: Kline & Company

There are additional fuels that are important in the fossil fuel market, i.e., natural gas and coal. Industrial customers have a choice between fuels, and they will select the one that is most appropriate for them and provides the lowest cost option, taking into account their heating equipment design and proximity to fuel supplies or pipelines or rail spurs.

Although it is rare, there are times when the market prices of primary fuels diverge to such an extent that consumers consider switching from one fuel to another. This is what happened in the used oil burner market in 2008/2009, as shown in Figure 30.

Figure 30. Natural Gas and Fuel Oil prices ($/MMBtu)



Source: Energy Information Administration

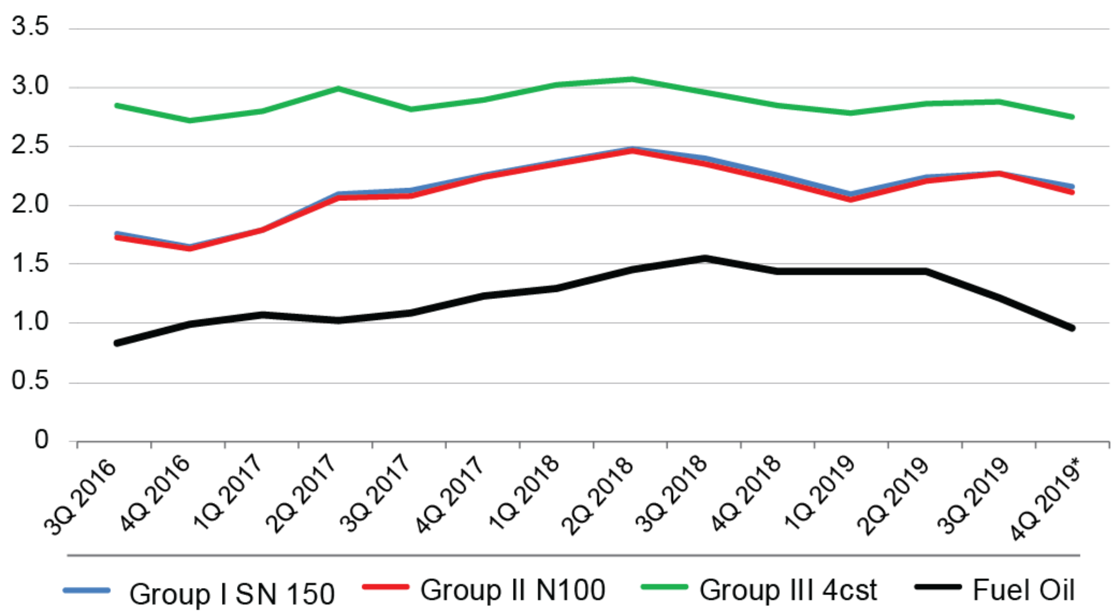
Figure 30 shows the same fuel oil price as in Figure 28; however, the units are shown as $/MMBtu because market natural gas prices are quoted in that unit. Gas prices are shown in red, and fuel oil prices are shown in black. As shown in Figure 30, they tracked each other quite well until 2008, when the shale gas boom occurred. Shale gas has changed the U.S. industrial fuel markets due to its low production cost and growing supplies, which is coincident with the advent of horizontal drilling and hydraulic fracturing. At the same time, fuel oil prices generally continued their traditional relationship to crude oil. The impact on the used oil business was dramatic, as many of the used oil customers realized they could significantly reduce their energy cost by switching to natural gas. If their facility was in close proximity to the natural gas pipeline network, many invested in the facilities required for fuel switching. Other industries also witnessed significant changes; for example, in the power industry, many coal-fired power plants switched to natural gas, which had the added benefit of reducing carbon dioxide (CO_2) emissions. The impact on the used oil industry was to create a surplus of used oil and motivate the re-refiners to expand or build new facilities to absorb the imbalance. It also motivated exports of used oil to Latin America mostly for utilities' needs.

Base Stock Prices

Figure 31 shows the relationship between fuel oil prices and base stock prices expressed in $/gallon over the last three years. Three grades of base stocks are noted because the lubricant market is evolving to higher quality oils, and with supporting economic conditions, re-refiners always have the option of which grade to produce. In this chart, fuel oil prices are shown in black, and three types of base stock prices are noted, relating to Group I, II and III grades. Group I (in blue) is the traditional lubricant base stock that is manufactured with the solvent extraction process, which has been the mainstay of the business since the 1930s. However, higher quality Group II stocks (in red) are becoming predominant now, which are produced by a more severe refining process involving hydrocracking.

Finally, even higher quality Group III base stock prices (in green) are growing in the marketplace, and some industry observers predict that they will become more prevalent in the future. U.S. virgin base stock manufacturers can manufacture all three groups of oils, but Group I manufacturing is on the decline, as it is being replaced by Group II demands—particularly for motor oils. While Group III base stocks can be manufactured in the United States, it is currently more economic to meet demand from overseas suppliers who can manufacture them at lower costs. This latter factor reflects two major advantages: (1) access to waxy Asian crudes, and (2) access to gas to liquids technology—both of which result in lower Group III production costs compared to U.S. lube refiners.

Figure 31. Base Stock vs. Fuel Oil Price Trends – U.S. Gulf Coast ($/gallon)



Source: Argus Media, December 2019

Figure 31 shows that fuel oil is a driver of the base stock market. In fact, VGO is an essential feedstock for U.S. lubricant manufacturing, while it is also an important blend stock in fuel oil blending. It is this margin or uplift between fuel oil prices and base stock prices that provides the financial incentive to invest in re-refining facilities. While the market prices (bulk cargoes in the U.S. Gulf Coast) set the basis for the economic drives, they must be translated to the local market conditions in the immediate area of the re-refining plant and by operating costs for fuel, labor, depreciation, chemicals, and other direct plant manufacturing expenses. It has been estimated that the investment required for a re-refining plant is on the order of $2–$3/gallon of annual capacity.[164] For example, Avista Oil, using its proprietary patented technology, built the most recent grassroots plant in 2013 at a cost of $95 million, which translates to $2.0/gallon annual throughput.[165] Direct manufacturing costs for used oil re-refining to base stocks have been estimated in the range of $0.75 to $1.00 per gallon.[166]

Used Oil Discount

Figure 32 shows the estimates of U.S. re-refining discount. This 'discount' reflects the fact that the price received by used oil refiners for their re-refined base stocks does not meet the market price of virgin base stocks. It shows that over the last 10 years or so when re-refiners sold their base stocks in the market, the price that they were able to achieve was only about 85 percent of the market price for virgin crude oil produced base stocks. This reflected the fact that consumers were not convinced that re-refined base stocks were totally interchangeable with virgin stocks. However, over time, final product blenders and consumers have gained more experience and confidence in the quality of re-refined base stocks such that currently only a 5 percent discount is applied vs. market prices. This is a significant improvement and testifies to the successful efforts on the part of re-refiners to ensure the increasingly high quality of their products.

2020 IMO Sulfur Regulations and Implications for Used Oil

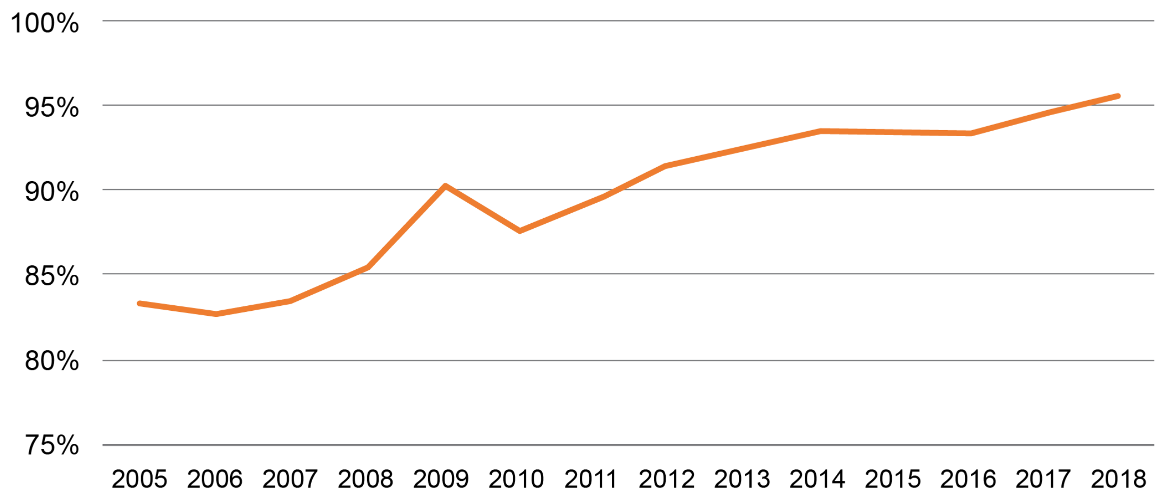
In January 2020, IMO, an agency of the United Nations, implemented regulations limiting marine bunker sulfur content to a maximum of 0.5 wt. percentage from the previous sulfur cap of 3.5 wt. percentage.[167] The sulfur reduction presents a significant challenge to global refining and marine shipping industries, with major shifts in crude/refined products' supply and demand. The impacts of the low sulfur regulations will be reflected in prices and differentials across most refined product markets. Accordingly, the IMO regulations will have implications for used oil and re-refining markets.

The 2020 IMO bunker sulfur regulation represents the first major global fuel regulation and will be implemented through a newly established international compliance mechanism. Furthermore,

[164] Data provided by Kline & Company.
[165] Data provided by Avista Oil.
[166] Data provided by Vertex Energy.
[167] International Maritime Organization, Frequently Asked Questions: The 2020 global sulphur limit, *available at* http://www.imo.org/en/MediaCentre/HotTopics/GHG/Documents/2020%20sulphur%20limit%20FAQ%202019.pdf.

the regulations provide for an alternate compliance option involving high sulfur bunker fuel, with ship stack flue gas scrubbers to reduce sulfur emissions. These factors will serve to add to uncertainty in the market, which will be reflected in product market pricing and volatility.

Figure 32. Estimates of the U.S. Re-refining Discounts Over Time
(RRF Group II as a Percentage of Virgin Group II)



Source: Kline & Company

IMO Regulations

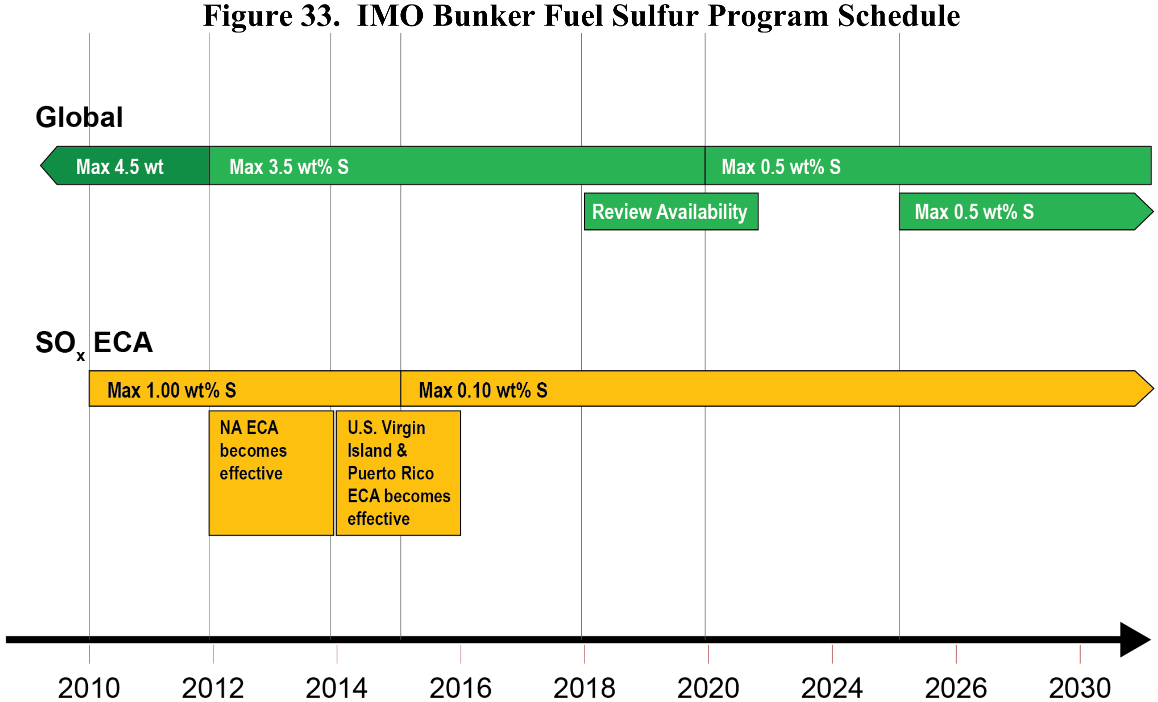
IMO is responsible for safety and security of international shipping and prevention of environmental pollution from ships. Over the last 10 years, IMO has developed a comprehensive program for control of sulfur and nitrous oxide emissions from ship fuel combustion. Under the new IMO regulation, ships are required to use marine fuels with no more than 0.5 wt. percentage of sulfur content as opposed to previous limit of 3.5 wt. percentage sulfur content. Prior to 2012, the sulfur limit was 4.5 wt. percentage. The schedule is shown in Figure 34, which also shows that prior to formal adoption, a global review process conducted in 2018 concluded that adequate supply and compliance measures would be in place, and the program should move forward.

Figure 33 also shows an additional aspect of the IMO's pollution prevention program covering Sulfur Emission Control Areas (SECA), which are areas that apply for additional control measures and are approved by IMO for such designation. Current bunker sulfur limits for SECAs are 0.1 wt. percentage as set in 2015. This applies to bunker fuel consumption within a 200 nautical-mile radius of the area's coastline. There are currently three SECAs: (1) the Baltic Sea and North Sea (essentially Northwest Europe); (2) the East Coast of North America, including Canada, the United States; and (3) Puerto Rico/Virgin Islands.[168] The impact of the 2020 sulfur reductions will be somewhat diminished in these areas, as a major portion of their international bunker supply is already very low sulfur.[169]

The IMO program provides ship operators an alternative compliance option for meeting the goals of the sulfur control program through control of combustion stack emissions. Shippers can continue using high sulfur bunker fuel by installing stack gas scrubbers to reduce flue gas sulfur emissions. Once scrubbers are installed, the ship owner can continue to burn high sulfur bunker fuel, which is expected to be cheaper than the mandated low sulfur fuel. Investments in scrubbers; however, are expensive, involving millions of dollars for individual large ocean-going vessels. Ship owners will consider all options when deciding their preferred path. In some cases, it may be more practical to scrap a ship if it is approaching retirement age and invest in newer technology vessels.

The IMO fuel regulations are the first case of international marine fuel quality control. Compliance will rely on ship flag countries and ports under a newly established and untried program. Compliance concerns and supply/demand challenges and uncertainties are likely to lead to initial non-compliance, supply/demand constraints, and significant price volatility.

Figure 33. IMO Bunker Fuel Sulfur Program Schedule



Source: Hart Energy and various other sources

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[168] International Maritime Organization, Sulphur oxides (SO_x) and Particulate Matter (PM) – Regulation 14, *available at* http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-(SOx)-%E2%80%93-Regulation-14.aspx.
[169] These areas will still be influenced by IMO impacts on international fuel supply/demand/pricing.

International Bunker Fuel Market and Production

The international bunker fuel demand is currently about 4.2 million barrels/day. It consists of 0.8 million barrels/day marine gas oil (distillate), and the remainder is heavy/residual marine fuel. The heavy/residual fuel includes the heavy industrial and utility sectors. Bunker fuel represents a slightly over half of the total heavy/residual fuel market. Bunker fuel is currently made up of almost entirely high sulfur fuel, whereas some of the other sectors also use low sulfur fuel. The bunker sector is growing, while the other sectors are in decline due largely to fuel substitution (e.g., natural gas in the power utilities industry).

While the bunker heavy/residual fuel market represents less than 4 percent of global refined products, it plays a significant role in crude oil markets, as well as in balancing refining and refined product demand. High sulfur bunker is produced almost exclusively from refining high sulfur crudes, and its demand plays a role in high sulfur crude processing capacity and potentially high-low sulfur crude market price differentials.

Refinery production of high sulfur residual, which exceeds the demand for high sulfur residual fuel production (and asphalt production), must be processed in refinery heavy fuel processing facilities (e.g., catalytic cracking, hydrocracking, or coking) for conversion into other light products and petroleum coke currently in demand. Bunker residual demand will therefore impact the global need for refinery heavy oil processing capacity, for which spare capacity is limited. A tight balance between surplus heavy high sulfur residual fuel and heavy oil processing capacity will expand heavy-light product price differentials with downward pressure on heavy high sulfur fuel markets.

Response to IMO and Impact on Refined Product Markets

While there is uncertainty on how industry will meet the IMO requirements, the strategy will involve some combination of a shift to alternate fuels (marine distillate/gas oil or a “hybrid” lighter fuel, natural gas), production of a compliant low sulfur heavy/residual fuel, use of ship scrubbers, demand reduction via slow steaming, and noncompliance.

Based on published and internal analysis of options, Table 15 provides a forecast of compliance strategies shippers/refiners are expected to employ to meet IMO 2020. However, there is still significant uncertainty, and compliance strategies are expected to change over time.

The switch to marine gas oil will likely initially be the most prominent compliance option. Globally, there is adequate refining capability to supply the compliant gas oil and ships can accommodate the fuel quality change. The option will be expensive because of the large gas oil residual price differential and because the lower energy content of the gas oil will result in higher fuel consumption. Over time, higher costs of this option will provide the economic incentive for ship scrubbers, particularly on new builds. The gas oil strategy and its impact on pricing will decline over time.

Table 15. Forecast 2020 Compliance Strategies

Strategy	Compliance Share
Marine gas oil	45% - 55%
LS residual fuel	15% - 25%
Stack scrubbers	15% - 25%
Natural gas	<1%
Slow steaming	5% - 15%
Noncompliance	10% - 15%

Within this category, a shift to a hybrid fuel, which is a combination of heavy gas oil and a portion to the residual fuel (i.e., VGO). VGO, also the primary component of refinery base stock, is used primarily as cracking feed for conversion to diesel and gasoline. Therefore, the bunker fuel will compete with and reflect pricing of the cracking feed sector. Still, some degree of processing exists to make this fuel IMO compliant, and its quality and energy content is more suitable to the bunker market than traditional marine gas oil. As VGO is the predominant feedstock for lubes base stocks manufacturing, a direct connection between the IMO regulations and lubricants is unavoidable.

Low sulfur residual bunker can be produced in limited quantities by selectively processing and segregating residual produced from low sulfur crude oil and blending to bunker. Often, these higher quality residuals also serve as cracking feed, so there will be price competition from that sector. The large increase in U.S. tight oil crude oil has added to low sulfur residual supply thus making this blending option more feasible from a supply/demand point of view.

Ship scrubbers offer the most attractive long-term compliance strategy. Shippers were initially slow to commit to this remediation route due to uncertainties about the program, as well as the financial viability and the logistics of the installation process; however, recent demand in scrubber installation has been strong. The cost of scrubbers has decreased to about $3-5 million per unit in 2019, as compared with $5-8 million per unit in 2018. Several carriers that initially expressed doubts over the use of scrubbers have adopted these technologies as the installation costs became more appealing.[170] Over time, scrubber use will continue to expand, particularly as related to new builds.

Slow steaming, like all options, will depend on fuel and resulting costs, as well as on overall global economic activity and trade. Over time, this strategy will likely decline. Non-compliance will involve emergency waivers for supply unavailability and some initial deliberate cost driven non-compliance. Again, this category will decline over time.

[170] G Captain, "More Carriers turn to Scrubbers Ahead of IMO 2020," *available a*t https://gcaptain.com/more-carriers-turn-to-scrubbers-ahead-of-imo-2020/.

Impact on Crude Oil and Refined Product Markets

The primary impact of the IMO 2020 sulfur limit will come from the shift in demand from higher sulfur residual to marine gas oils, i.e., a significant increase in demand for low sulfur distillates and a surplus of high sulfur fuel oil. Figure 34 shows the trend in bunker fuel anticipated before and after implementation of IMO and the anticipated longer-term trend. While there are uncertainties on timing and extent of the impact of IMO 2020 on markets, as illustrated in Figure 34, trends indicate longer-term marine gas oil shift to hybrid fuel and reduction in non-compliant fuel. Marine gas oil demand will increase by more than 1 million barrels/day or about a 3.5 wt. percentage increase in global gas oil/distillate demand. The incremental requirement will tighten the gas oil market, resulting in increasing prices. Meanwhile, the high sulfur residual market will be in surplus, with supplies significantly exceeding demand and coinciding price decline. The price spread between gas oil and high sulfur residual fuel will widen significantly.

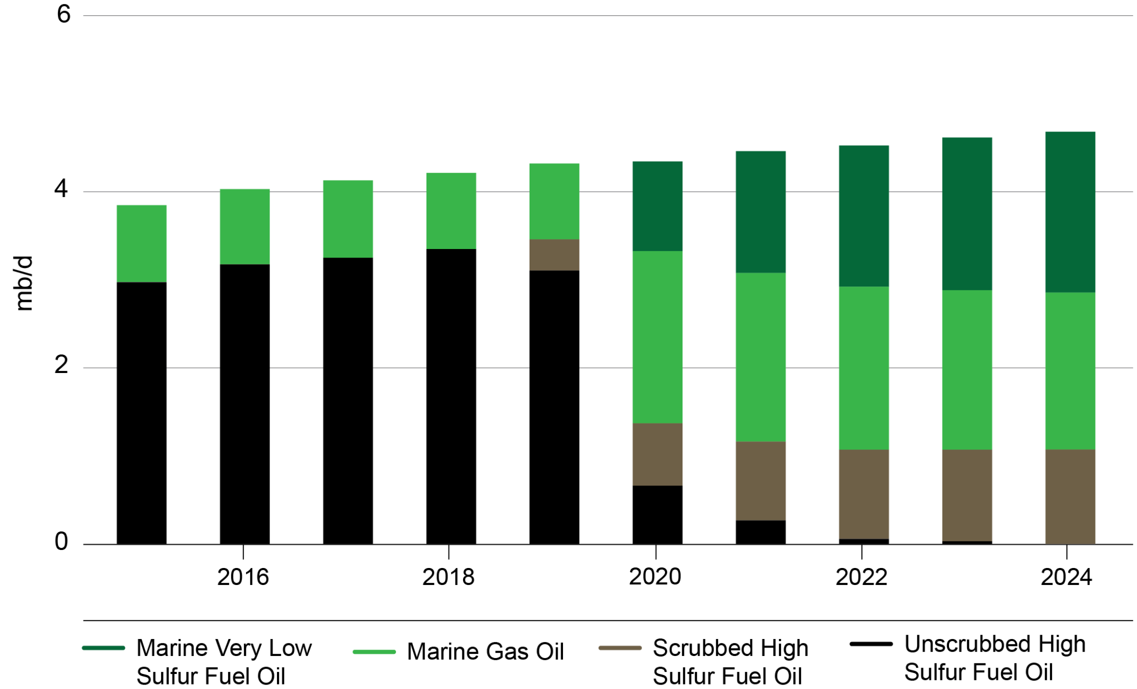
Longer-term, there will be a small decline in the use of marine gas oil and an internal shift to the hybrid (VGO based) fuel. In addition, there will be less surplus non-compliant fuel as more market is created for high sulfur use with scrubbers. The combination of the two will offset some of the initial expansion of price differentials. The surplus high sulfur residual fuel will also place additional demand on refinery high sulfur conversion capacity, further depressing the high sulfur residual fuel market. Again, over time the price impacts will be diminished.

Demand and production of low sulfur residual bunker will draw on available low sulfur crude oil and tend to increase low sulfur-high sulfur crude oil differentials. Low sulfur residual production will also draw higher quality feedstocks from the competing refinery conversion processing, driving low sulfur residual prices and low sulfur-high sulfur residual differentials higher. Within the marine gas oil sector, the heavier VGOs for hybrid fuel production will be more desirable because of their quality and energy characteristics. Competition with refinery conversion feed markets will place a premium on VGO streams.

Implications for Used Oil and Re-refining

Overall, there will be a global trend of declining high sulfur heavy fuel markets and increasing premium on distillate gas oils and VGOs. Used oil tied to high sulfur fuel will face a long market, with lower used oil value. To the extent used oil can be re-refined and directed to low sulfur markets, this can be offset. On the other hand, VGO will become more desirable in the gas oil market, while experiencing continued competition for use as high-quality refinery conversion processing feed. VGO prices will increase relative to other residual fuel components and products. Lube base stocks are VGO based and will see a comparable market price impact. As VGO prices increase in value, this will put pressure on base stocks prices, as VGO is the primary raw material for base stock production. This will, in turn, put pressure on finished lubricants prices. In any case, it is likely that re-refining businesses will see margins improve as their feedstock prices decline with the possibility of increased product values.

Figure 34. Bunker Fuel Market by Fuel Type (MBD)



Source: Energy Information Administration

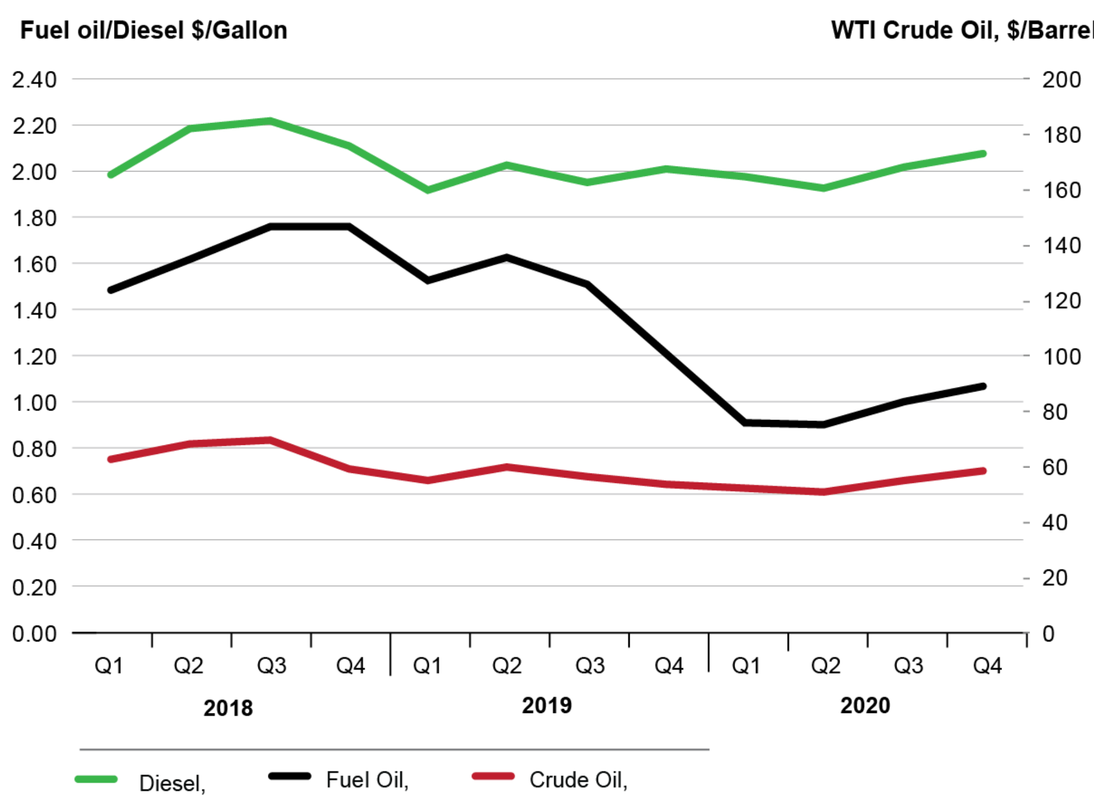
North America has already implemented the SECA sulfur controls for fuel consumption within 200 miles of the coastline. This has been accomplished almost exclusively by switching to marine gas oil. The remaining international bunker market served from the United States is small and will likely remain high sulfur. The U.S. refining industry has extensive conversion capacity to adjust high sulfur residual production as required to adjust to declining international demand. With existing capacity and shifting crude production, U.S. refiners will likely be capable of increasing conversion processing of high sulfur residual from the current bunker market or international market surplus. Price relationships should trend similar to the international market, but with less volatility.

In summary, value of used oil in traditional fuel markets will decline, as will the overall size of the fuel market. Base stock value will see an upward trend as VGOs increase. The overall result will be potential for improved re-refining margin. Figure 35 shows the recent trend of fuel oil, diesel fuel, and crude oil prices, as well as the forecast for the next year according to the EIA Short Term Energy Outlook (October 2019). It reveals a drop of nearly 50 percent in fuel oil prices, driven primarily by the impact of the new IMO regulations. In fact, the market is already starting to anticipate these changes, and oil stocks are being reduced with the resultant recent decline in fuel oil prices in the second half of 2019. WTI crude oil and diesel prices are shown for reference.

With the lower prices for fuel oils, collectors and burner fuel processors will come under pressure as their revenues tied to fuel oil prices will decline. This will be a major challenge for both the used oil industry and the re-refining industry. After all, the re-refining industry is reliant on the collectors to provide supplies for their operations. This situation may motivate some consolidation in industry, whereby re-refiners increasingly cooperate financially with collectors. This could take the form of joint ownership, buyouts, or other pricing schemes to ensure that collectors will remain financially viable.

Longer term, price trends are more uncertain. For example, if ship owners continue to invest in scrubbing technology, thus increasing their ability to burn higher sulfur fuels, it could lead to stronger demand and higher prices for high sulfur fuel oils in the coming years.

Figure 35. Near Term IMO Impact on Fuel Oil Prices [171]



[171] U.S. Energy Information Administration, "The Effects of Changes to Marine Fuel Sulfur Limits in 2020 on Energy Markets" (March 2019).

X. Used Oil Contaminant Best Practices

Private sector entities and government organizations responsible for the collection of used oil are susceptible to having used oil that contains contaminants from physical or chemical impurities including PCBs. Physical impurities such as dirt, metal scrapings, or sawdust and chemical impurities, such as solvents, halogens, or saltwater can contaminate oil during handling, storing, and processing. Proper sealing and handling of oil will minimize the occurrence of physical impurities from the environment, however physical impurities within machinery components such as abrasives, metal scrapings, or grindings can occur. Physical impurities are removed during the pretreatment, and filtering and demineralization processes to remove inorganics and additives. Preventing used oil storage from becoming a catch-all and ensuring used oil is separated from other wastes such as antifreeze and wastewater can minimize environmental exposure to physical impurities. Additionally, preventative maintenance and appropriate lubricant selection to meet viscosity and operating temperatures can reduce machinery internal metal scrapings or grinding.

PCBs are a group of chemicals composed of carbon, hydrocarbon, and chlorine atoms. Since PCBs can behave similarly to dioxins, they are considered highly toxic to human and ecological receptors at low levels and are very difficult to remediate due to slow decomposition.[172] PCBs were manufactured over 50 years—from 1929, until they were banned in 1979. Due to their non-flammability, chemical stability, high boiling point, and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications.[173] Testing for PCBs is expensive ($60-150 per test) and can be difficult to identify during analyses; therefore, scientists and regulatory agencies have been researching ways to find cheaper and more accurate ways to test for PCBs.[174]

EPA provides best management practices for commercial and municipal used oil collection centers and recyclers to reduce the spread of PCB contamination in used oil and decrease the frequency of PCB contamination.[175] As used oil collectors pick up oil from a variety of commercial and municipal centers, the PCB concentration in the oil is unknown. When a concentration of PCBs greater than 50 ppm is introduced into used oil, the entire volume, which otherwise generally could be recycled and reused, must be disposed of in accordance with the TSCA regulations. All tanks, equipment, and vehicles must be decontaminated, and the PCB-contaminated oil must be disposed of in accordance with the PCB regulations (40 CFR Section 761.50(b)(1), which can be quite costly.[176]

[172] Trihydro, "Debated Use of Method 1668B for Analysis of PCBs" Liquid Recycling, Issue 3 at 14 (2012), available *at* https://view.joomag.com/liquid-recycling-2012-issue-3/0950256001361294285.

[173] U.S. Environmental Protection Agency, "Learn about Polychlorinated Biphenyls (PCBs)" (2019), *available at* https://www.epa.gov/pcbs/learn-about-polychlorinated-biphenyls-pcbs#healtheffects.

[174] Trihydro, "Debated Use of Method 1668B for Analysis of PCBs" Trihydro, Liquid Recycling, Issue 3 at, 2012, Page 14 (2012), *available at* https://view.joomag.com/liquid-recycling-2012-issue-3/0950256001361294285. https://view.joomag.com/liquid-recycling-2012-issue-3/0950256001361294285.

[175] U.S. Environmental Protection Agency, "Preventing and Detecting PCB Contamination in Used Oil" (February 2018), *available at* https://www.epa.gov/sites/production/files/2018-01/documents/placeholder_for_pcbs_in_used_oil_fact_sheet.pdf.

[176] *Ibid.*

EPA-recommended best practices for commercial and municipal used oil collection centers include the following actions: [177]

- When feasible, collection centers should obtain a sample of used oil from each batch received, known as a retain sample. If PCBs are detected in the collection tank, these samples can be analyzed to determine the source of PCBs.
- Sample from the collection tank before shipping the used oil off-site. Lock and label used oil tanks immediately after sampling. If the space and funds are available, use dual-compartment tanks or dual tanks, where one side or tank can be locked when full to await test results, while the other side or tank remains open to collect used oil.
- If the used oil in a tank contains quantifiable levels of PCBs, but less than 50 ppm PCBs, use the retain samples to determine whether the PCBs are from a source greater than or equal to 50 ppm that has been diluted. If used oil contains greater than or equal to 50 ppm PCBs or contains less than 50 ppm PCBs as a result of dilution, label the tank or container, and notify the State and regional PCB coordinators immediately. If the source is less than 50 ppm, consult the State environmental agency regarding any State requirements for management.
- Offer to submit test results to used oil recyclers prior to pick up. Testing for PCBs in oil can only be done by accredited laboratories to be defensible. Field test kits cannot reliably detect PCBs in used oil. As of 2017, a sample analysis cost is in the range of $60–$150 per sample, depending on desired turnaround time.
- Post signs at collection facilities, providing notification that only used oil should be put in tanks. All containers used to collect, and store used oil should be clearly labeled with the words "Used Oil."
- Keep all used oil collection containers and tanks closed and secured in a fenced area or inside a building to prevent access when the collection center is closed.
- If possible, a staff person at the collection center should document the owner and source of the used oil. Do not add used oil from potential PCB-containing sources (e.g., transformers, capacitors, hydraulic equipment, pre-1979 brake fluid, etc.) to non-PCB used motor oil.

[177] U.S. Environmental Protection Agency, "Preventing and Detecting PCB Contamination in Used Oil" U.S. Environmental Protection Agency, (February 2018), *available at* https://www.epa.gov/sites/production/files/2018-01/documents/placeholder_for_pcbs_in_used_oil_fact_sheet.pdf

EPA-recommended best practices for used oil recyclers include the following activities: [178]

- Educate commercial and municipal collection centers and transporters on the importance of preventing the mixing of potentially PCB-contaminated oil with other used oils, such as used motor oils.
- Obtain analytical results showing the PCB concentration from each collection tank at a commercial or municipal collection center prior to pick-up. Signed certifications do not absolve any facility from obligation to comply with applicable regulations or excuse any facility from enforcement.
- Ensure analytical lab results are submitted to used oil recyclers as opposed to relying on word-of-mouth or experience.
- Offer to analyze samples from commercial and municipal collection centers prior to pick-up if they decline to submit test results. Analyzing samples in advance of pickup could prevent contamination of the tanker truck. Provide simple sample collection equipment with easy-to-follow instructions to help collection centers take accurate samples of their oil to send to the recycler or to an accredited laboratory for testing before shipment to the recycler.
- Take a retain sample from each incoming shipment of used oil. Offload the used oil into a guard tank, which should remain locked while waiting for PCB test results. Guard tanks reduce cleanup costs if a used oil shipment is contaminated with PCBs.
- If PCBs are detected in the used oil at the guard tank, analyze retain samples collected prior to pickup to find the likely source.
- Maintain records that document the testing and analysis of used oil samples to determine the presence and concentration of PCBs prior to any processing or re-refining of the used oil.
- Follow the applicable EPA SW-846 testing procedures and protocols (e.g., EPA Method 8082A with Method 3580A extraction and Method 3620C or 3665A cleanup).
- When taking a retain sample of each batch collected during a pick-up run, collect a duplicate sample in a separate sealed container that can be kept for future reference.
- Keep a defensible chain of custody for the duplicate sample. Document and verify each transfer of custody.
- For analysis of samples, only use labs that follow approved EPA analytical methodology and that have quality assurance management programs. Facilities with their own labs can develop their own Quality Assurance Project Plans (QAPP).

Commercial and municipal used oil collection centers and recyclers should be able to significantly reduce the incidence and extent of PCB contamination by following these best

[178] *Id.*

practices.[179] In addition to implementing these best practices or taking other actions to address sources of PCB contamination, facilities should always ensure compliance with all applicable State and Federal regulations.

EPA's best practices are intended to reduce the presence and occurrence of PCBs in used oil collection; however, PCB contamination does occur. In a survey of 25 oil recyclers by NORA, the cost of responding to a PCB incident ranged from a low of $39,000 to a high of $15 million, with the average cost for the survey respondents' largest PCB incident equaling $1.98 million.[180]

[179] *Id*.
[180] David G. Coles for NORA, "PCB Infiltration into the Used Oil Recycling System: Causes, Costs, and Corrective Actions" (April 6, 2016), available *at* https://cdn.ymaws.com/www.noranews.org/resource/resmgr/TSCA_Reform_Effort/NORA_PCB_Rept_4-6-16.pdf.

XI. Used Oil Industry Stakeholders Perspectives

Used oil is a valuable resource that impacts many stakeholders in private and government sectors across re-refiners, burners, and collectors and distributors, as well as oil industry advocates and representatives.

The UORC vision is one that is shaped by and benefits from close focus on the used oil molecule. As the quality of the used oil molecule has improved steadily, the used motor oil pool is populated with higher quality lubricants. UORC focuses on enhancing resources previously invested into the lubricant molecule from original crude extraction, refining, and importing. The coalition believes that valuing the used oil molecule based solely on its heating content (i.e., burning) is an increasingly out-of-date approach to what could otherwise be a strategic advantage in better resource management, leading to energy independence and energy dominance.[181] The used lubricant molecule is valued because of its increasingly higher quality as a feedstock and not simply for its heating content. If the used lubricant molecule is valued based on its increasingly higher quality as a feedstock and not simply for its heating content, UORC believes that a hierarchy of disposition routes is likely more important today than when it was embraced in the previous decade. UORC does not intend for a hierarchy to limit or discourage other legal dispositions, but rather to serve as a framework within which the used oil refining industry can collaborate on a defined strategy that benefits stakeholders across the value chain. UORC believes used lubricant refining should be viewed as a strategic provider of petroleum products rather than a simple waste repository.

NORA encourages the increased responsible collection of used oil, promotion of sustainable reuse of used oil by Federal agencies, and dissemination of public information concerning sustainable reuse options for used oil. NORA recommends the Federal Government collect or facilitate an effort to accurately quantify used oil generated and collected on a recurring basis.[182] NORA also encourages EPA to re-consider its stance on PCB contamination to encourage used oil collection. To promote the sustainable reuse of used oil, NORA recommends the Federal Government coordinate with various stakeholders for common messaging, identify current efforts related to used oil, and evaluate what can be enhanced. Additionally, NORA advises that without more enforcement, economic incentives to properly manage used oil generated may decline at the generator level and more charge-for-my-oil may lead to non-permitted and illegal activity.

API takes the position that the primary focus of Federal strategy should be on ensuring the increased collection of all used oil generated in all areas and markets, including those that have been viewed as hard to reach and regulate. The strategy should encourage a portfolio of environmentally acceptable used oil dispositions as a necessary step to facilitate a robust demand for used oil across varying broader market conditions. API notes that the greatest environmental

[181] "UORC's Comments on the October 16th Stakeholder Workshop Meeting" Correspondence from UORC, November 7, 2019.
[182] "Increasing the Beneficial reuse of Used Lubricating Oil," NORA, October 16, 2019.

benefit that a Federal strategy for used oil management could deliver would be to decrease the amount of used oil that goes uncollected and, thus, may be disposed of improperly.

Further, API indicated that a lack of accurate and comprehensive used oil data has impeded overall improvements in used oil management.[183] A challenge to improving the understanding of the collection of used oil for proper disposition is the historic lack of data on the amount, location, and characteristics of used oil that is generated but not collected.[184] API recommends that DOE work with industry, State agencies, and other interested stakeholders to develop a cost-effective periodic survey to establish a baseline estimate of the amount and dispersion of used oil available for collection, then repeat the survey as appropriate to gauge the success of subsequent used oil collection efforts.

In a recent LCA, API concluded that impacts of uncollected used oil are significant, and no single disposition yields the lowest impact under all conditions. API advises that any disposition preference should not jeopardize collection rates, and there should be a periodic survey of used oil use volumes and a review of worldwide used oil programs conducted to identify and foster used oil collection. API's perspective on a Federal strategy is that the Federal Government should focus on identifying market-enhancing mechanisms and protocols to measure and increase the collection of used oil. Additionally, API advises that a Federal strategy should allow the marketplace to develop and maintain a broad portfolio of used oil dispositions related to both lubricant petroleum products and fuel petroleum products, and any strategy should not institute market-distorting biases that favor any single used oil disposition route.

API states that it encourages the development of cost-effective technology for identifying PCB contamination in used oil, as well as work toward a more equitable approach to assigning liability for the introduction of PCB-contaminated used oils among the parties involved in the generation, collection, and disposition of used oils. Finally, API has indicated that it strongly encourages forming an advisory group of used oil stakeholders to provide input to the Federal Government on unresolved issues identified concerning strategies to promote the beneficial utilization of used oil within the broader petroleum products marketplace.[185]

According to API, there is some level of acknowledged technical complications in the re-refining of used oils from lubricants containing notable levels of select bio-based or ester base oils. API recommends that such complications and their implications be further clarified and, potentially, reflected in modifications to the currently stated differing utilization preferences by Federal agencies related to lubricants either with bio-based or with re-refined oil content.

AOCA represents thousands of automotive maintenance centers throughout North America. AOCA states that it supports NORA's proposed solution for PCB-contaminated DIY used oil, recognizing the difference between unintentional and intentional dilution, and eliminating and/or reducing notices of violation. According to AOCA, penalizing responsible management of PCB-contaminated DIY used oil does nothing to protect the environment, but it does bleed the

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[183] "API Perspectives and Recommendations on Federal Strategies for Used Oil Management" API Used Oil Task Force, October 16, 2019
[184] Ibid
[185] Correspondence with API, November 8, 2019

resources necessary to do so. AOCA also supports incentives for re-refining and other forms of recycling on-spec used oil. Further, AOCA supports enhanced voluntary compliance auditing for recyclers so that the generator and transporter community can identify the most responsible used oil recyclers—reducing their risks of being held liable for downstream pollution resulting from used oil collected from their locations.

Rock Energy Systems (RES), LLC (a parent company of three leading brands of space heating products) estimates that between 80 million and 120 MMG of used oil are combusted annually in an estimated 100,000 heaters in U.S. small businesses, based on customer lists and industry sales data.[186] It is RES' perspective that it is economically advantageous for owners to combust their oil in a space heater for energy recovery. According to RES, the economic benefit of disposing used motor oil in space heaters outweighs the benefit they derive from having their oil collected and paying for another heating source. RES estimates a typical installation will pay for itself over the course of two heating seasons. It is RES' position that oil generators' ability to displace a virgin fuel and heat their facilities are a significant benefit of using used motor oil, thus generators will continue to choose to dispose of their used motor oil in space heaters. RES firmly believes the space heater industry continues to provide great benefit to the oil generators and to the used oil management in the United States. RES states that by providing an alternative to third party collection, it supports the value proposition for used oil in the U.S. economy and adds great economic benefit to those that generate used motor oil.

Hydrodec of North America, LLC, provides the perspectives of a specific subset of the used oil recycling business, transformer oil re-refiners. Hydrodec collects used transformer oil in the field from transformers that have reached the end of their 20–30 year working life or become damaged as a result of weather. The company's clients are typically utilities and government entities. Hydrodec generates carbon credits for every ton of CO_2 displaced by recycling used transformer oil, which are provided to the utilities supplying the used oil for re-refining. Further, Hydrodec is permitted to store and treat PCB-contaminated transformer oil because the company's catalytic hydro-treating process destroys PCB molecules commonly found in transformer oil.

Hydrodec believes that re-refining of transformer oil should be mandatory in the United States or, at the very least, encouraged as a "best practice," as it keeps the oil in use for an indefinite period and keeps it from being discarded, which causes pollution and exposes utilities to possible litigation. Hydrodec believes that transformer oil should be included along with lubricating oil in any DOE efforts to enhance collection efforts.

Additionally, Hydrodec believes that the Federal Government should consider mechanisms for denoting the destination of all used oil through a system of "Certificates of Origin" that maximize opportunities for re-refining used transformer oil in the United States. In so doing, Hydrodec argues, the government would provide transparency into the waste streams of utilities and improve control over the chain of custody. According to Hydrodec, with the use of Certificates of Origin, an internal and external audit process could be introduced—enabling visibility of the destination of all used transformer oil, while promoting re-refining. This practice

[186] Correspondence with Rock Energy Systems, LLC, October 21, 2019.

could end the current situation, where such oil is exported via inefficiently monitored export routes to and within Mexico for use as a diesel extender, among other things.

XII. Specific Steps to Improve Collections and Increase Re-refining and Other Beneficial Reuse of Used Oils

Discussion of 2006 Report Recommendations

The 2006 report listed recommendations for the Federal Government to consider for improving the collection of used oil and increase re-refining.[187] These are summarized below, grouped under five categories, together with comments regarding their current status.

1. Information Exchange to Encourage Used Oil Recycling

Consider establishing an information exchange to include State personnel involved in used oil management and industry stakeholders. The broad objectives would be to:

- Allow States that do not have active recycling programs to benefit from the experiences of those that have well-established and successful programs by identifying best practices, potential funding mechanisms, and potential financial incentives for collectors and recyclers;
- Serve as focal point for disseminating technical information regarding environmental and energy-related issues involved with used oil management;
- Investigate ways to increase used oil collections in lower population density areas (rural and farming communities) where recycling options are less convenient;
- Identify ways to improve public awareness and education programs that communicate the benefits of recycling used oils, particularly to cost-conscious DIY consumers (e.g., bilingual outreach in targeted areas); EPA's "You Dump It, You Drink It" Campaign[188] could be used as a model for this effort; and
- Assess the magnitude of added costs associated with collectors handling used oil that has become contaminated with hazardous materials and recommend mitigation.

Status: *This information exchange activity was not formally instituted. However, during data gathering for this updated report, multiple stakeholders supported the idea of creating some type of stakeholder meeting framework that could be used to put forward ideas, provide data for policy development, and support continued public/private collaboration. Accordingly, this recommendation is brought forward as part of the current report's recommendations, which are outlined later in this section.*

[187] U.S. Department of Energy Office of Fossil Energy, Used Oil Re-Refining Study to Address Energy Policy Act of 2005 Section 1838 (2006).
[188] EPA, https://archive.epa.gov/wastes/conserve/materials/usedoil/web/html/ydiydi.html.

2. Retail Sales Outreach

Consider Federal Government support of Statewide initiatives to require all retail establishments that sell quart and gallon containers of motor oils to proactively communicate locations of local recycling centers that accept used oil free of charge.

Status: *During the years since the 2006 report was published, the number of motor oil retail outlets actively accepting used oil from customers has increased dramatically. Outlets like AutoZone, for example, promote their willingness to accept used motor oil from customers; 95 percent of the stores accept used motor oil (not including Alaska), and their website notes that 9.5 MMG of oil was collected in 2018.*[189] *However, there is no Federal requirement that motor oil vendors must also accept used oil for recycling. Many States require retailers to post notices informing customers that dumping used oil is illegal and noting where collection sites are located.*[190]

There is no defined regulatory mechanism for the Federal government to require States to require retail establishments to post specific information regarding used oil at their stores. However, there may be a way for the Federal government to encourage wider recycling through publicizing multi-State websites (e.g., Earth911.com). Accordingly, this recommendation is brought forward later in this section.

3. Technical Analyses

Consider updating studies that relate to used oil management, both from an environmental and energy consumption perspective, which could take into account the latest technology developments for both used oil processing and re-refining, as well as the growing role of synthetic lubricants. These could include:

- LCAs on the energy balances and environmental impacts associated with various used oil end use alternatives;
- Studies on used oil recycling programs and current used oil dispositions to assess how much progress has been achieved and where efforts to increase collections should be focused; and/or
- Studies on the health and safety aspects of used oils and re-refined oils, including specific toxicity issues and quality standards.

Status: *During the years since the 2006 report was published, States, API, and government researchers in Europe and elsewhere have conducted several LCAs (discussed in Section VIII of this report). DOE has not performed any LCA or other studies focused on used oil since the 2006 report was published. However, during data gathering for the current report, multiple stakeholders supported updating scientific analyses of used oil processing with regard to both energy/environmental LCA and improved quantification of used oil collection and disposition.*

[189] AutoZone, https://www.autozone.com/landing/page.jsp?name=in-our-stores.
[190] Minnesota PCA, https://www.pca.state.mn.us/sites/default/files/w-hw4-36.pdf.

Accordingly, this recommendation is brought forward as part of the current report's recommendations, which are outlined later in this section.

4. State Adoption of Used Oil Management System Standards

Pursuant to Section 3006 of RCRA, consider encouraging those States that have not yet adopted the Used Oil Management Standards in 40 CFR Part 279 to do so.

Status: *During the years since the 2006 report, all States and Washington, D.C. have either adopted 40 CFR Part 279 or promulgated regulations that are very similar. There is no longer any need for Federal action in this regard.*

5. Space Heater Policies

For those geographic areas not attaining the National Ambient Air Quality Standards ($PM_{2.5}$ and PM_{10}) consider reassessing policies for used oil-fired space heaters. Estimating the number of units and quantifying hazardous air pollutant emissions from those units could also be considered. The purpose of this assessment is to establish the impact of these combustion units on nonattainment of National Ambient Air Quality Standards. Further, for those States that offer State tax incentives to small businesses to promote purchase of space heaters for responsible recycling of used oils, consider conducting surveys with these businesses to confirm whether the results of those programs justify the costs involved. It is possible that a given State would be better served by channeling those public funds into expanding collection centers and financing recycling efforts as opposed to subsidizing space heaters.

Status: *No action was taken on this recommendation after the 2006 report was published. There were differing opinions on this topic raised during stakeholder input meetings carried out for the purpose of updating the 2006 report. Some stakeholders believe that fueling space heaters with used oil is neither energy efficient nor environmentally friendly and hinders increased collection for processing and re-refining. Others believe that space heaters provide flexibility and cost savings to small businesses, as well as a practical path for recycling used oil in certain situations that can be carried out with minimal environmental impacts. They also believe that restricting space heaters' use may not necessarily lead to increased collection of used oil but could lead to increased illegal disposal. Accordingly, this report includes a recommendation for further study.*

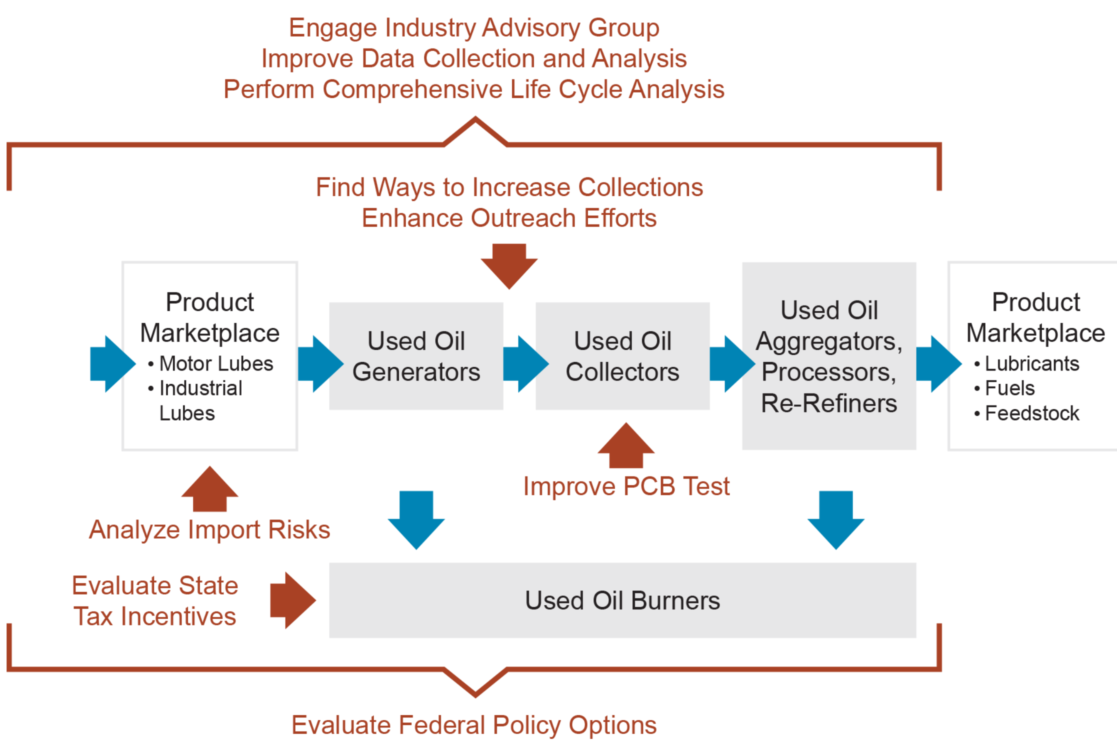
Recommendations for Specific Steps to Improve Collections and Promote Sustainable Reuse of Used Oil

This 2019 report's updated recommendations are outlined below. The legislation directing this update requires that DOE consult with relevant Federal, State, and local agencies and affected industry and stakeholder groups; update data that was used in preparing the 2006 report; and prepare and submit to Congress "a coordinated Federal strategy to increase the beneficial reuse of used lubricating oil," that:

- Is consistent with national policy (Used Oil Recycling Act of 1980 - Public Law 96–463);
- Addresses measures needed to increase the responsible collection of used oil and disseminate public information concerning sustainable reuse options for used oil; and
- Promotes sustainable reuse of used oil by Federal agencies, recipients of Federal grant funds, entities contracting with the Federal Government, and the general public.

Accordingly, 18 recommendations are grouped below within four general areas: (1) Information Exchange and Outreach, (2) Data Collection and Research, (3) Data Analysis, and (4) Policy Development. The alignment of these actions across the range of stakeholder categories is portrayed in Figure 37.

Figure 37. Alignment of Recommendations Across Used Oil Stakeholder Categories



Further action will require that Congress provide direction and resources enabling-Federal agencies to engage and work together on implementing these recommended actions.

Information Exchange and Outreach Recommendations

- Establish a Stakeholder Advisory Group to gather and evaluate additional information related to used oil collection and re-use, to address unresolved issues identified in this updated report and beyond, and to develop strategies to promote the beneficial utilization of used oil. This group should include members of all stakeholder groups, whether directly or through industry association, including refiners, re-refiners, processors, generators, collectors, burners, State regulators, and non-profits associated with waste management and recycling. The Stakeholder Advisory Group should meet at a frequency determined to be most effective for the generation of useful advice and timely review of analytical products produced under other recommended actions outlined in this report.
- Work with relevant agencies to review and, where appropriate, refresh and enhance webpages related to used oil recycling and regulations. For example, collect data and information to update EPA's public website information related to used oil management (i.e., *Managing Used Oil: Answers to Frequent Questions for Businesses*).[191]
- Investigate ways to inform do-it-yourself oil changers of the locations of used motor oil recycling locations via a centralized website.
- Based on the flexible "best practices" data collected from State surveys (see section below), investigate ways that Federal action might be used to increase used oil collections in lower population density areas (rural and farming communities) where recycling options are less convenient, and identify ways to improve public awareness and education programs that communicate the benefits of recycling used oils, particularly to specific subsets of DIYs.

Data Collection and Research Recommendations

- Carry out research and data collection activities to better quantify estimates of (1) oil losses in use, (2) volume of used oil generated and collected, (3) volume of used oil burned or recycled onsite or lost to the environment, (4) volume of used oil burned as used oil, and (5) volume of used oil processed to RFO and blended into HSFO or exported as used oil. This effort should be carried out in a scientifically rigorous manner based on statistically valid surveys. The data collection effort should be designed in a manner that enables it to be maintained on an annual or otherwise periodic basis to provide an ongoing database for future analysis of the relative changes of these values over time.
- Using National Laboratory resources, carry out a scoping study to investigate the potential benefit of a National Laboratory research effort to develop an inexpensive, disposable, quick test kit for testing used oil for the presence of PCBs.

[191] https://www.epa.gov/hw/managing-used-oil-answers-frequent-questions-businesses.

- Work with State regulators to collect and compile State-level data on used oil collection and disposition. Survey State regulators and develop a comprehensive set of "best practices" that provide insights on how to encourage used oil collection through State policies. Publish and promote the dissemination of this document.
- Collect information on and evaluate foreign used oil collection programs and identify "best practices" and insights for U.S. policies.

Data Analysis Recommendations

- Utilizing National Laboratory resources, carry out a comprehensive LCA that quantifies the relative energy and environmental costs of (1) re-refining used oil to produce lubricants, (2) burning used oil, and (3) re-refining or processing used oil to non-lubricant products. Make certain that this analysis reflects the most up-to-date technologies and practices utilized in the United States, as well as the impacts of expected future changes in technology and lubricant requirements. This LCA should not be duplicative with existing used oil LCAs.
- Using data collected (see above section), carry out analyses of used oil recycling programs and current used oil dispositions to determine where to focus efforts to increase collections.
- Encourage State agencies in selected States that offer State tax incentives to small businesses that buy space heaters to confirm whether the results of those programs are aligned with State objectives.
- Work with the Department of Commerce and other relevant agencies to evaluate the economic and security risks, if any, of a sudden cut off in Group III lubricant imports, as well as to predict the likely responses of both the crude oil refining and the used oil re-refining industries to such an event. Assess under what situations or scenarios Group III lubricant imports might be curtailed (e.g., as a result of global events, including curtailments of Group III base stock production due to operational problems, such as manufacturing plant mishaps or geo-political developments involving the producing countries).

Policy Development Recommendations

- Consider the potential economic benefits of implementing policies that would eliminate or reduce notices of violation and allow industry to manage used oil in "as-found" condition. Further, evaluate options for supporting a more equitable approach to assigning liability for the introduction of PCB-contaminated used oils among the parties involved in the generation, collection, and disposition of used oils.
- Conduct analysis to evaluate whether the inclusion of bio-based lubricants in the used oil collection stream contaminates the feedstock or negatively impacts the re-refining process. Undertake a study of technical complications in the re-refining of used oils from

lubricants containing notable levels of select bio-based or ester base stocks and their implications should be completed.

- Evaluate the costs and benefits of tax incentives that encourage the re-refining of used motor oil, such as:
  - Investment tax credits and/or production tax credits to encourage the collection and refining of used motor oil and other used lubricating/industrial oils,
  - Incentives to discourage the burning of used motor oil and other used lubricating/industrial oils,
  - Incentives for domestic production of Group III lubricants,
  - Income tax deductions for any payment for used oil collection of oil that is re-refined, and
  - Direct and indirect market impacts of the above incentives.
- Consider options for providing grant funding or other incentives under the DOE's Clean Cities Program, or other similar programs for use of oils refined from used motor oils.
- Consider Federal options for supporting enhanced voluntary compliance auditing for used oil processors and re-refiners so that the used oil generator and transporter community can more easily identify the most responsible used oil recyclers.

XIII. Conclusion

P.L. 115–345 directed DOE to review and update a report on the energy and environmental benefits of the re-refining of used lubricating oil. This report updates the 2006 report on the energy and environmental benefits of the re-refining of used lubricating oil and includes 18 recommended actions to be taken by DOE, independently and in coordination with other government agencies and entities, to improve collections of used lubricating oil and increase re-refining and other beneficial re-use of such oil. To prepare this update DOE met on multiple occasions with representatives of stakeholder groups within the used oil sector and carried out independent research.

Each stakeholder group within the industry has unique perspectives on the priorities for Federal Government policy and potential actions to encourage more efficient recovery and re-use of used oil. The re-refiners, who have increased used oil re-refining capacity over the past decade, seek to increase the volumes of used oil available for collection and processing and increase opportunities to market higher-quality versions of their base oil product in response to increasing demand. Used oil collectors, a stakeholder group which has undergone significant consolidation over the period between the reports, seeks to find ways to increase collection efficiency and improve profit margins that are being squeezed by lower oil prices. Used oil generators hope to avoid the costs of used oil contamination due to unknown do-it-yourself sources and maintain flexibility in their ability to burn used oil as a fuel substitute on their own premises. Crude oil refiners want to maintain an even playing field and avoid the implementation of policies that might favor one base oil option over the other.

All stakeholders agree on the benefits of increased used oil collections, reduced improper disposal, as well the collection and publication of improved and regularly updated industry data. Accurate analysis of the used oil marketplace in the United States is hindered by a lack of detailed data regarding the volumes of oil lost in use, collected, uncollected, improperly disposed of, burned and processed. Another area of agreement is related to the need for improved methods for detecting and preventing used oil with toxic constituents (e.g., PCBs) from complicating the recycling process.

Conservation and recycling of the Nation's used oil "resource" makes sense. It extends the life of our national crude oil resources, it reduces the likelihood of improperly disposed of used oil making its way into the environment to contaminate soil and water, and it is energy efficient, as it can take less energy to recycle used oil than to create new lubricating oil from virgin crude oil. Further, used oil recycling supports thousands of direct and indirect jobs, generates tax revenue and helps provide consumers with a range of economical product choices. Government policies that help to ensure a well-functioning used oil marketplace will help to deliver these benefits.

XIV. Appendices

Appendix A – Lubricants Primer

Appendix B – Processing and Re-refining Technology

Appendix C – Used Oil Sector Stakeholders Background Information

Appendix D – Highlights of Key Federal Statutes and Regulations that Relate to Management of Used Oil

Appendix E – Example of State Used Oil Management Legislation: California

Appendix F – Results of Internet Search for State Used Oil Programs

Appendix G – Life Cycle Analysis Supplemental Information

Appendix H – Used Oil Industry Stakeholder Interactions

Appendix A – Lubricants Primer

There are over 3,000 lubricant products in the global market that support a variety of applications that involve automobiles, marine engines, aviation engines and turbines, compressors, hydraulic equipment, as well as ultra-highly refined oils that are used in food processing equipment and cosmetics. Each product has a distinct formulation that is made up of crude oil derived base stocks (in most cases) and various additive compounds used to offer specific qualities for the intended applications. Engine oils represent the highest volume segment of global lubricant sales. This 'Primer' focuses on the evolution of that segment of the business more so than the other products due to the size of the business and also because the used oil industry is heavily involved in recycling engine oils.

The most critical qualities, particularly of an automobile engine lubricant, include the following:

- Ability to *maintain lubricity* under a wide range of operating temperatures and pressures, which means it must have a high enough boiling point such that it does not vaporize under expected operating environments, as well as low temperature properties such that it can be pumped in cold environments. Also, under high temperature conditions, lubricating oils must retain their chemical and liquid properties to avoid degradation and chemical breakdown.
- Ability to demonstrate a *high viscosity index,* which means that it retains its viscosity qualities over a wide range of operating temperatures, thus ensuring protection of critical operating components.

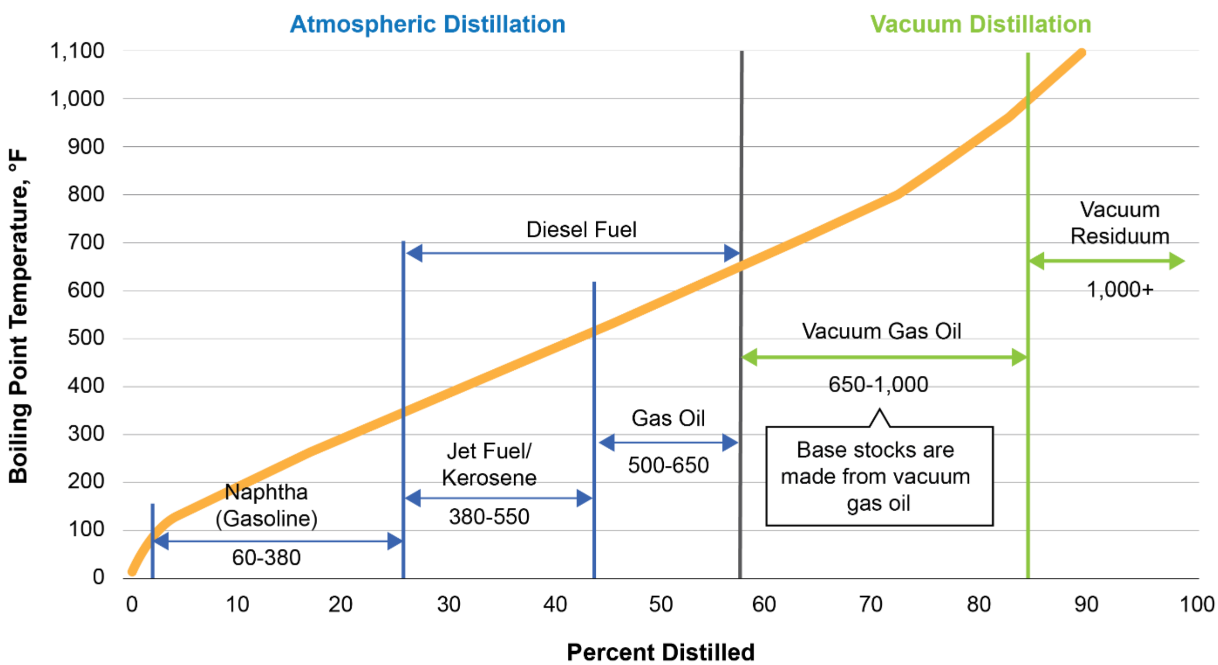
These quality requirements are met by mixing two primary types of materials: base stocks and additives. Mineral base stocks are oils that are manufactured directly in oil refineries, while additives are manufactured by specialty chemical manufacturers. As marketplace or government regulated qualities evolve over time, both base stock and additive packages must adapt as well. This section focuses primarily on the role of base stocks in meeting evolving quality requirements.

Types of Lubricants

As shown in Figure 3, the major products include: (1) passenger car motor oils (PCMO); (2) process oils, such as oils used directly in the manufacture of tires and process heating fluids; (3) general industrial oils used to lubricate a variety of mechanical equipment such as pumps; (4) compressors; (5) rotating equipment hydraulic fluids; (6) industrial engine oils used primarily in diesel engines and marine engine lubricants; (7) metalworking fluids used in the process of forming and shaping various metal shapes; and (8) greases. Other specialty oils include jet engine lubricants; white oils that are used in a wide variety of applications where no toxicity levels can be tolerated, such as cosmetic formulations; and food processing equipment lubricants. Synthetic lubricants, which are not derived directly from crude oil, but offer superior qualities in specific applications (e.g., high-quality motor oil lubricants, jet engine lubricants, and aviation hydraulic oils), are growing in importance.

As shown in Figure A-1, crude oil derived lubricant base stocks—the most common component of all lubricants—are derived from a narrow range of crude oil in the 650–1,000°F boiling range and are produced predominantly in the vacuum distillation refining process. Following vacuum distillation, a number of different refining processes are used to further improve the qualities of base stocks, which will be discussed in more detail later.

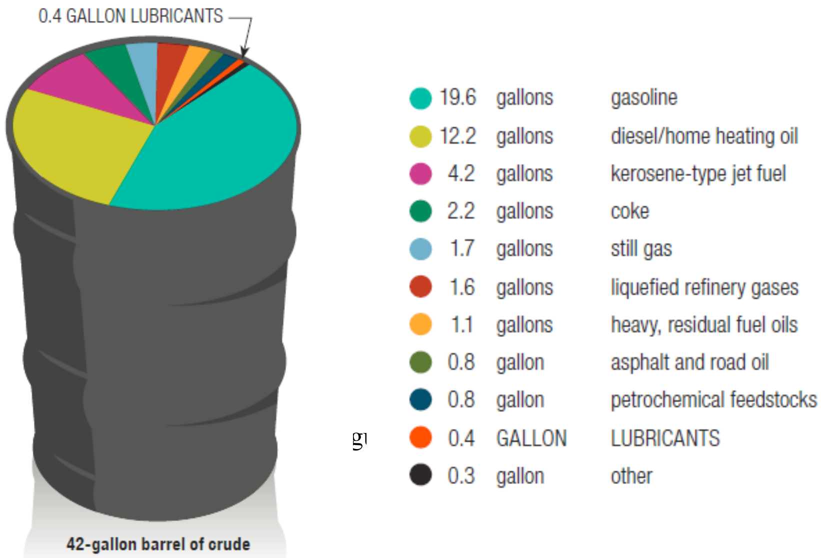
Figure A-1. Typical Crude Oil Boiling Curve – True Boiling Point vs. Yield



Source: Chevron

As shown in Figure A-2, the actual average volumes of lubricants that can be derived directly from crude oil amount to a very small fraction, compared to other large-volume products like gasoline, diesel fuels, jet fuel, fuel oil, etc. In fact, less than 1 percent of the typical crude oil barrel will yield the qualities that make up lubricant base stocks. However, certain crude oils from the U.S. (e.g., Louisiana crude), Saudi Arabia, or elsewhere can have higher yields. Although all lubricant products evolve, from a quality point of view and taking into account new applications, motor oil qualities have evolved perhaps faster than any other lubricant product group. One key driving force behind these improvements in motor oils has been mandated improvements in automobile gasoline mileage and emission requirements (addressed in the following section in more detail).

Figure A-2. Average Volumes of Lubricants from a Barrel of Crude Oil



Source: Lubes’N’(… g

Lubricant Groups

This evolution of base stock quality is manifested in more demanding specifications, and the ‘Group’ number is the label used to distinguish more recent developments, with Group I being the industry standard up to the turn of the last century. These base stocks were produced using conventional solvent extraction and dewaxing technologies, which were initially developed in the 1920s. However, as quality requirements became more stringent (particularly for motor oils), in the 1990s, industry adapted to Group II base stocks, which often involve severe hydrocracking and dewaxing technologies. Currently, Group III base stock demand is increasing and may have a dominant position in the future. Group III uses the same basic technology as Group II, but at even higher processing severities. In addition, Group III base stock production is growing in the international markets, where they can be produced from gas-to-liquids technology or by refining higher quality Asian waxy crudes that can be more economically transformed into Group III base stocks (compared to the normal crude oil types processed in the United States). Table A-1 shows the differences between Group I, Group II, and Group III base stocks.

Table A-1. API/ATIEL Base Stock Classification System [192]

Group	Saturates	(% Wt)	Sulfur (% Wt)		VI
I	<90	and/or	>0.03	and	80 < VI <120
II	≥90	and	≤0.03	and	80 ≤ VI <120
III	≥90	and	≤0.03	and	≥ 120
IV	PAO (Polyaphaolefins)				
V	All stocks not included in Groups I-IV and VI				

- Gp I: Lower performance applications
- Gp II: High performance & higher viscosity applications
- Gp III: High performance & low viscosity applications

Source: Chevron

- Group I – Manufactured by solvent extraction, solvent or catalytic dewaxing, and hydro-finishing processes. Common Group I base stock are 150SN (solvent neutral), 600SN, and 150BS (brightstock).
- Group II – Manufactured by hydrocracking and solvent or catalytic dewaxing processes. Group II base stock has superior anti-oxidation properties since virtually all hydrocarbon molecules are saturated.
- Group III – Manufactured by special processes such as isohydromerization. Group III can be manufactured from base stock or slack wax from dewaxing process.

Figure A-3 highlights the quality differentials between base stocks, which shows that Group II base stocks are essentially 'water white' in color, while conventional Group I base stocks can exhibit a yellowish tinge.

Figure A-3. Group I vs. Group II Base Stock

Group I Solvent Processing
- Refines by subtraction
- Some unsaturated and polar components remain in base oil
- Lower purity

Group II Hydroprocessing
- Refines by conversion
- Higher purity
- Better oxidation stability
- Very low aromatics

Source: Chevron

[192] ATIEL: Association Technique de l'Industrie Européenne des Lubrifiants.

The improved motor oil quality requirements have motivated improvements in both additive and base stock qualities. The most critical quality differences between the 'Groups' focus on the paraffin content, aromatic content, sulfur content, and the viscosity index.

Lubricating oil base stocks are a mixture of paraffinic (or saturated) compounds and aromatic compounds. Aromatic compounds are less desirable because they degrade or oxidize faster over time compared to paraffinic compounds, and they require very expensive refining processing steps. Viscosity index is a critical quality variable for base stock because it indicates the ability of the base stock to retain viscosity at increasing engine temperatures. When an oil is heated, its viscosity reduces; but modern base stocks are chemically designed to better retain their viscosity characteristics in a rising temperature environment, thus ensuring better protection for critical engine components. Sulfur and phosphorous content are also important quality indicators because they must be restricted to protect catalytic converters.

Over the last 20 years, Group I base stocks made up approximately 50 percent of the total production capacity of base stocks in North America. Group II base stocks made up approximately 30 percent. But, the demand for Group II base stocks has grown significantly, and they are currently the largest volume produced. Group III base stocks are produced only in limited volumes in the United States, and most of the Group III base stocks are imported. Although the United States has capacity to produce additional volumes of Group III base stocks, imported base stocks can be produced much cheaper outside United States, with lower cost and higher-yielding raw materials that can be used in Asian markets and in the Middle East to manufacture the higher-quality Group III base stocks.

The next section details the factors that drove the need for higher quality base stocks.

Impact of CAFE Standards

The following discussion focuses primarily on motor oils because that product group represents the largest volume of lubricant product demand. While most lubricant qualities remain somewhat fixed with modest quality improvements over time, compared to other products, passenger car motor oils qualities have become significantly more stringent over time.

Perhaps the most significant driving force behind the drive to improve lubricant quality over time has been the imposition of Corporate Average Fuel Economy (CAFE) standards, which regulate the passenger car and light-duty vehicle performance improvements, specifically the mileage per gallon (mpg). This quality trend has been driven by a number of factors, including crude oil supply vulnerability, environmental factors (like smog), and global climate change issues. The standards were first adopted in the 1970s in response to global oil shortages experienced during the Arab oil embargo. Recognizing that motor gasoline consumption was the most sizeable element of U.S. total hydrocarbon demand, the objective was to reduce crude oil imports and dependency on OPEC countries by mandating higher mileage automobiles. Average gasoline mileage for passenger car motor vehicles was on the order of 10–15 mpg, whereas today, new cars are achieving over 38 mpg. Currently, the primary focus is on reducing fossil fuel consumption even further, which is consistent with global climate change initiatives. All of these initiatives impact gasoline quality and demand directly, and they have a significant impact on motor oil lubricants. Diesel engine oils have also experienced regulated quality changes, but they were focused more so on emissions-related concerns with mandated reductions in NO_X and particulate emissions.

CAFE standards are regulated by Department of Transportation’s National Highway Traffic and Safety Administration (NHTSA), which sets and enforces the CAFE standards, while EPA calculates average fuel economy levels for manufacturers and also sets related greenhouse gas standards. NHTSA established CAFE standards under the Energy Policy and Conservation Act of 1975, as amended by the Energy Independence and Security Act (EISA) of 2007, while EPA establishes greenhouse gas emissions standards under the Clean Air Act. The improvement in vehicle mileage is shown in Figure A-4.

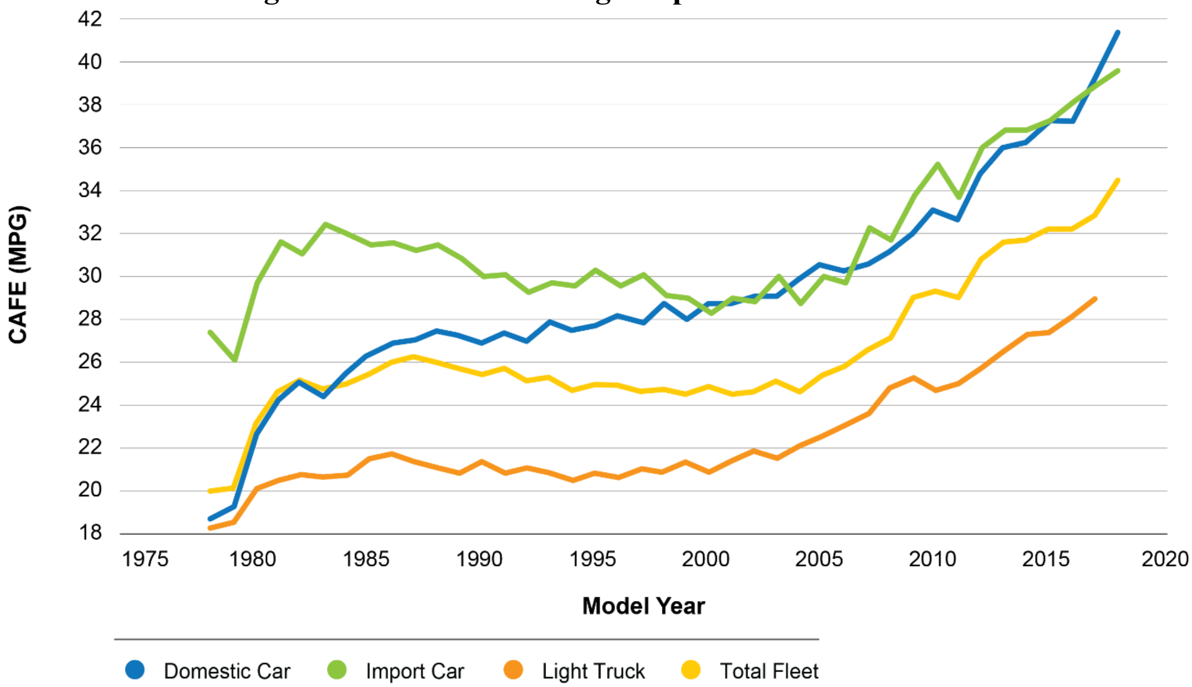
The CAFE standards in a given model year define the mpg levels that manufacturers' fleets are required to meet in that model year, which are dependent on the characteristics and mix of vehicles produced by each manufacturer. Penalties can be applied if the average fuel economy of a manufacturer's annual fleet of vehicle production falls below the applicable requirement. The new CAFE standards not only improve energy efficiency of the Nation’s fleet, but also:

- Reduce U.S. petroleum consumption,
- Increase the availability of alternative fuel vehicles,
- Promote the advancement of innovative technologies, and
- Lower greenhouse gas emissions, helping to mitigate climate change and improve air quality.

Passenger cars are commonly pressed with “stricter” emissions and efficiency rules than trucks and SUVs, and the CAFE standards are no exception. Under the current laws, passenger cars are required to reach 54.5 mpg by 2026.

To achieve the mandated CAFE improvements, the automobile industry developed vehicle enhancements, including engine design, enhanced combustion technology, vehicle weight reductions, and other design improvements. These include performance characteristics that require higher quality lubricating oils and other characteristics; for example, improved piston deposit protection in high temperature environments, sludge control, wear protection, oxidation resistance, seal compatibility, turbocharger protection, emission control system compatibility, and protection of engines operating on ethanol-containing fuels. In response, these changes led to the need for improved lubrication properties, which drive the lubricants industry product developments.

Figure A-4. Vehicle Mileage Improvements Over Time [193]



Additionally, to ensure the quality of motor oils over time, volatility restrictions have been imposed that, with the advent of synthetic oils (like polyalphaolefins), extended oil drain intervals have been enabled, and thus reducing used oil generation.

Role of Key Industry Organizations

The following section serves to identify the key organizations that are responsible for establishing and maintaining motor oil quality standards and developing techniques to ensure that consumers are aware of emerging trends. Automobile manufacturers work with these groups to adopt and communicate standards that form the basis for original equipment manufacturer (OEM) recommendations set forth in the operating manuals of new vehicles

American Petroleum Institute (API)

Establishing, managing, certifying, and communicating the quality and performance standards of motor oils is a complicated process in which API plays a pivotal role. As noted on the API website,[194] API's Engine Oil Licensing and Certification System (EOLCS) is a voluntary licensing and certification program that authorizes engine oil marketers that meet specified requirements to use the API Engine Oil Quality Marks. Launched in 1993, API's Engine Oil Program is a cooperative effort between the oil and additive industries and vehicle and engine manufacturers Ford, General Motors, and Fiat Chrysler and those represented by the Japan

[193] Source: National Highway Traffic and Safety Administration (NHTSA)
[194] https://www.api.org/products-and-services/engine-oil

Automobile Manufacturers Association and the Truck and Engine Manufacturers Association. The performance requirements and test methods are established by vehicle and engine manufacturers and technical societies and trade associations such as the American Society for Testing and Materials (ASTM), the Society of Automotive Engineers (SAE), and the American Chemistry Council (ACC). The Engine Oil Program is backed by a monitoring and enforcement program that ensures licensees adhere to program requirements. This includes running physical, chemical, and performance tests on licensed engine oils and verifying that the API-registered marks are properly displayed on containers and convey accurate information to consumers.

The lubricant manufacturers must provide evidence to API that their lubricant oil formulations meet the minimum performance standards. For example, API requires that the lubricant manufacturers perform engine tests to demonstrate that their products will withstand the more stringent operating performance requirements of new engine designs. Those products that meet the requirements are then licensed to display the API 'donut' on their packaging—providing confidence to the car owning public that they are buying the right product for their car as required by the automobile manufacturer to validate the warranties. It specifies the SAE viscosity grade and the API service classification.

Society of Automotive Engineers

SAE classifies motor oils based on two primary criteria: the ability of the oil to flow under low temperature conditions and the viscosity of the oil at higher temperatures (100° Celsius). These use the label of *xxW-yy* where *xx* is an indication of oil to flow under winter temperatures (the lower the *xx,* the lower the temperature that it can accommodate), and *yy* is an indication of the viscosity of the oil at higher temperatures. For example, a 5W oil can operate at lower temperatures than a 10W oil, and the high temperature viscosity of a SAE 10W-30 is lower than the viscosity of a SAE 10W-40. Most new cars today require a 30 viscosity rating (or lower), as recommended by the OEMs to validate warranty protections. Table A-2 shows the grades that can meet the winter criteria.

Table A-2. SAE Viscosity Grades for Passenger Car Motor Oil

Multigrade oils as SAE 5W-30 and 10W-30 are widely used because, under all but extremely hot or cold conditions, they are thin enough to flow at low temperatures and thick enough to perform satisfactorily at high temperatures. Note that vehicle requirements may vary. **Follow your vehicle manufacturer's recommendations of SAE oil viscosity grade.**

If lowest expected outdoor temperature is	Typical SAE viscosity grades for passenger cars
0°C (32°F)	0W-20, 0W-30, 5W-30, 10W-30, 10W-40, 20W-50
-18°C (0°F)	0W-20, 0W-30, 5W-20, 10W-30, 10W-40
Below -18°C (0°F)	0W-20, 5W-20, 5W-30

In addition to these improvements related to CAFE standards, the automobile and lubricants industries themselves have developed enhancements like extended oil drain intervals, which, in addition to other properties, require lower volatility oils and increasing the use of highly processed mineral or synthetic base stocks like PAOs.

Although not addressed in this report, there are parallel improvements for heavy-duty engine oils (for diesel engines). While gasoline engine passenger car motor oils have been predominantly driven by mandated improvements in mileage efficiency, mandated improvements over time in the environmental emissions from diesel engine vehicles have focused on air quality with restrictions on NO_x and particulates, which in turn have motivated more stringent qualities of heavy-duty engine oils for diesel engines.

Impact of Modern Automobile Technology on Oil Change Intervals

Growing environmental concerns and tightening fuel efficiency norms, as well as lubricant product innovations, are bringing changes to the North American consumer automotive lubricants market. While it has remained flat in the last five years, the market is now experiencing a fast change in the quality levels of lubricants. The consumption of synthetic and semi-synthetic products, particularly in the United States and Canada, is growing and resulting in extended average drain intervals for passenger vehicle lubricants. Thus, despite a growing passenger vehicle parc in these countries, the demand for consumer automotive lubricants is declining.[195]

Modern automobile engines are designed and built to exacting standards and require oils that meet very specific industry and automaker specifications to ensure a long service life. Most late-model cars require synthetic-blend or full-synthetic, low-viscosity, multi-grade, resource-conserving oils that minimize friction and maximize fuel economy. It used to be normal to change a vehicle's oil every 3,000 miles, but with modern lubricants, most engines today have recommended oil change intervals of 5,000 to 7,500 miles. Moreover, if a car's engine requires full-synthetic motor oil, it might go as far as 15,000 miles between services.[196] A few examples of recommended oil change intervals are shown in Table A-3.

Synthetic oils are much cleaner than conventional oils, which means there are no compounds found in the oil that can lead to a faster build-up of sludge. Even modern conventional engine oil lasts longer than before, simply because of its improved durability. Another considerable contribution to the extended intervals between recommended oil changes comes from the refinement of the engine. Primarily, this is due to a reduction in tolerance, the gap between the metal moving parts in a vehicle. Decreasing these gaps allows the engine to use less oil. However, such engines with tighter tolerances need thinner (synthetic) oil.[197]

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[195] https://klinegroup.com/changing-consumer-automotive-lubricant-quality-levels-in-north-american-market-present-opportunities-as-well-as-challenges/.
[196] AAA, "How often should you change your engine oil?," *available at* https://www.aaa.com/autorepair/articles/how-often-should-you-change-engine-oil, accessed November 13, 2019.
[197] "Why modern vehicles don't require frequent oil changes," 2016, *available at* https://carlifenation.com/why-modern-vehicles-dont-require-frequent-oil-changes/.

Electric Vehicles: Growing interest and demand for electric vehicles (EV) in the United States is expected to impact the demand for consumer engine oils in the future. Environmental and air quality concerns, as well as evolving mobility patterns, have also contributed to the emergence of EVs, such as battery EVs, plug-in hybrid vehicles, and hybrid vehicles. As a result of supportive U.S. policy for EVs, automobile manufacturers are already divesting from conventional internal combustion engines, thus adding momentum to the growth of EVs in the United States. The penetration of EVs is forecast to reach 34 percent of the consumer vehicle parc by 2040.[198]

Table A-3. Examples of Recommeneded Oil Change Intervals

Brand	0W-20 Synthetic Oil	5W-20 Conventional Oil
Lexus [199]	10,000 miles or 12 months	5,000 miles or 6 months
Mercedes Benz [200]	10,000 miles or 12 months	NA
BMW [201]	Required at 10,000 miles for 2014 or newer models; 7,500 miles recommended	NA
Toyota [202]	10,000 miles or 12 months	5,000 miles or 6 months
Acura [203]	5,000 miles	5,000 miles
Audi [204]	10,000 miles	NA
Ford [205]	7,500 miles or 6 months for 2008 and newer models	5,000 miles or 6 months
Porsche [206] (911-997 Series)	20,000 miles or 2 years	NA

The increase in the number of all-electric and hybrid EVs will impact the types of lubricants needed for automobiles and the volumes of used oil generated. Lubricating an EV motor is very different from the same job for an internal combustion (IC) engine. An IC engine needs oil to minimize engine friction and act as a transmission fluid. EVs experience significant fluctuations in power flows and high motor speeds of up to 15,000 revolutions per minute. They can require several fluids, including oil for the gear reducer, which is the EV's transmission, and an oil specifically for the electric motor if the automaker is trying to improve cooling. Thermal management fluids for the battery and power electronics will likely play a role in the future to support demand for faster charging and stronger acceleration to increase range and ensure safety.[207] In addition, EVs may have somewhat different powertrain grease requirements.

[198] https://klinegroup.com/changing-consumer-automotive-lubricant-quality-levels-in-north-american-market-present-opportunities-as-well-as-challenges/.
[199] https://lexus2.custhelp.com/app/answers/detail/a_id/8201/~/what-are-the-oil-change-intervals-using-synthetic-oil%3F.
[200] https://www.mbgilbert.com/blog/when-should-i-change-the-oil-in-my-mercedes-benz/.
[201] https://www.bimmershops.com/bmw-oil-change.
[202] https://www.colonialtoyotact.com/blog/using-synthetic-motor-oil-changes-a-vehicles-maintenance-timeline/.
[203] https://www.karenradleyacura.com/blog/how-often-do-you-need-to-change-oil-in-acura/.
[204] https://www.blauparts.com/audi-oil-change/audi-oil-intervals.html.
[205] https://www.dennymenholtford.net/service/ford-oil-changes-butte-mt.htm.
[206] https://www.porscheriverside.com/service/porsche-911-997-series-service-intervals/.
[207] CNBC, 2019, "Lubricating Electric Vehicles," *available at* https://www.cnbc.com/advertorial/2019/01/10/lubricating-electric-vehicles.html.

The combustion engine in a hybrid vehicle will still need lubrication. These engines typically will have a smaller displacement (as the car also has an electric motor) and will not need to produce all the power a conventional vehicle would. With a smaller displacement, the requirements for heat and ageing stability will increase because more compact engines are also more encapsulated, which stresses the engine oil further. In smaller engines with high power, a turbocharger is often used. This increases the need for protection against deposits and places high demands on the oil.[208] However, the volume of lubricating oil needed to sustain an EV over its lifetime will remain substantially less than that needed for an IC engine.

Role of Additives

Lubricating oil companies use a variety of base stocks and additive technologies to develop proprietary formulations. Engine oils use base stocks that are enhanced with numerous additive compounds (e.g., anti-wear additives, detergents, dispersants, viscosity index improvers, chemicals to neutralize acids that originate from fuel and from oxidation reactions, and materials to improve sealing of piston rings). Table A-4 details the various types of additives that are used with base stocks to produce the desired qualities of final products. In the case of motor oils, typically 15 percent to 25 percent of the volume of finished product motor oils are additive components.

One key aspect of lubricating oils is that, as they age, they pickup contaminants from their application environments, and some of the additives and base stocks degrade over time as a result of their exposure to severe operating environments. However, most lubricants can be recycled and 'cleaned up' to such an extent that the base stock can be recovered to use for blending into a new lubricant. While virgin base stocks must start their processing evolution from the same starting point (i.e., crude oil), the quality of used motor oils continues to improve, allowing higher quality re-refined base stocks to be produced.

As noted in this section, the evolving technologies of passenger motor oils has led to this re-refining opportunity and is expected to continue to do so for the foreseeable future.

[208] "Electric cars – new technology calls for new lubrication," 2019, *available at* https://www.fuchs.com/dk/en/products/download-center/articles/electric-cars-new-technology-calls-for-new-lubrication/.

Table A-4. Principal Additive Chemistries

Function	Mode of Action	Key Chemical Types
Dispersants	Chelation of insolubes	Alkyl Succinimides, Alkyl Succinates, Alkyl Phenol Amines
Detergents	Surfactancy and michelle formation	Alkyl Metallic Sulfonates, Alkyl Metallic Phenates, Alkyl Metallic Salicylates
Antiwear	Formation of low-friction species on metal surfaces	Metallic Organo Dithiophosphates, Sulfurized Organics
Antioxidants	Oxidation chain inhibitors, peroxide decomposers	Metallic Organo Dithiophosphates, Alkyl Metallic Sulfonates
Anto-corrosion	Metal surface protection	Alkyl Phenols, Alkyl Amines, Metallic Organo Dithiphosphates
Antifoam	Reduction to surface tension	Silicones, Polymeric Acrylates
Demulsifier	Seperate water from oil	Ethoxylated or Propoxylated Polyamines of Polyols
Friction Modifier	Reduces surface roughness to facilitate oil flow	Sulfurized Organics, Specific Metallic Salts of Sulfurized and Phosphor-sulfurized Organics
Pour Point Depressants	Modifies wax structure in oil to improve low-temperature flow	Poly Methacrylates, Naphthalene Derivatives
V.I. Improvers or Modifiers	Differential temperature-related solubility in oil	Poly Methacrylates, Ethylene-propylene Copolymers
Extreme Pressure (EP)	Formation of low melting compounds on surfaces	Sulfurized Fats and Oils, Organo-phosphorus Compounds

Appendix B – Processing and Re-Refining Technology

The term "used oil refining" refers to any process applied to used oil that renders a primary final product (base stock) and may be used as the principal blending component in a lubricant. However, plants processing used oil for heavy distillate production may be converted into base stock refineries with the addition of back-end "polishing," so these are considered to be "quasi used oil refineries." Modern base-stock-producing used oil refineries typically consist of two primary processing stages after pretreatment: (1) thin film evaporation under vacuum to produce a VGO-like base stock precursor and to separate other less valuable fractions (asphalt extender, lighter distillates, and water) of used oil; and (2) "polishing" to produce API-specification base stocks, mainly Group I and II, employing hydrogenation, solvent extraction, or clay treatment.

Processes that are applied to used oil to produce products, which may be largely or totally intended for non-lubricating oil applications, consist of thermal distillation or chemical treatment processes designed to produce heavy distillates (including VGO, marine diesel, or cutter stocks), which are primarily channeled to refineries for conversion in fluidized catalytic cracking (FCC) or hydrocracking units for blending into heavy fuels. These so-called "VGO/MDO refineries" can often, with the addition of back-end hydrotreating, convert into base stock refineries; moreover, at times, base stock may elect to run only the front-end of their facilities if the price spread between base stocks and VGO is too low. Pre-treatment of used oil in processed fuel oil (PFO) or recycled fuel oil (RFO) plants is not considered used oil refining. Pre-treatment of used oil—consisting of various degrees of removal of solid wastes by filtration or centrifuging—and distillation to remove excess water and other contaminants (such as antifreeze) are primarily designed to produce a specification heavy fuel oil (often referred to as PFO or RFO in the United States).

Processing of used oil by both processors and re-refiners (categories where there is some degree of overlap, as the addition or subtraction of certain steps can allow one to become the other) begins with pre-treatment that includes solids removal with filtration and/or centrifuging. Following this, there are several processing stages designed to produce specific products, as shown in Table B-1. Each of these stages is discussed in greater detail in this section.

Table B-1. Used Oil Processing and Re-Refining Processes

Process	Input	Technology	Output
Solids removal	Raw used oil (may include contaminates such as antifreeze, solvents, etc.)	Centrifuges, filtration, chemical precipitants to remove sulfur and ash	Solids-free used oil that can be used as input to additional processing or markets as a fuel oil to plants
Thermal distillation	Solids-free used oil feedstock	Fractionation towers for separation of heated components at differing boiling points	Dehydrated used oil, wastewater, ethylene glycol, lighter distillates, cutter stocks
Vacuum distillation	Solids-free, dehydrated used oil	Fractionation towers for separation of components heated under low pressure	Vacuum gas oil (VGO), lighter distillates, marine diesel oil (MDO), cutter stocks
Vacuum tower thin film evaporation	VGO	Heat exchange process to separate lighter used lube oil fractions from heavier material	Lube oil base stocks of multiple grades, asphalt extender, crude oil refinery feedstock
Hydrotreating (hydrocracking)	Lube oil fraction	High temperature, high pressure addition of hydrogen in the presence of catalysts	Higher quality lube oil base stocks
Solvent extraction	VGO	Reaction of VGO with solvents to remove contaminants	Group I lube oil base stock
Acid clay treatment	Used motor oil	Reaction of used oil with sulfuric acid and clay to remove contaminants	Pre-treated used oil suitable for distillation processing
Clay treatment	VGO	Heated reaction with clay to remove contaminants and improve odor and color of product	Group I and Group II lube oil base stock

Thermal Distillation

Used oil is distilled in a three-stage distillation system. The first step, thermal distillation, removes the water and any light hydrocarbons (e.g., gasoline or solvents mixed into the used oil). The used motor oil temperature is raised through a series of heat exchangers before reaching an atmospheric flash drum, where the water and light hydrocarbons are evaporated. The vapors from the flash drum travel overhead through a condenser and are then further split into water and hydrocarbons in an oil-water phase separator. Any recovered light distillate fuel can be used as a supplemental fuel in process heaters on-site or sold as either an on- or off-specification used oil fuel. Recovered ethylene glycol (from antifreeze) is segregated and sold as a recyclable antifreeze product. The stripped water is removed as a side product and directed to the on-site wastewater treatment plant. The dehydrated oil is then subjected to a second, more severe distillation step, vacuum distillation.

Vacuum Distillation

During vacuum distillation, the oil is moderately heated under a vacuum, which causes the light fuels present to boil at lower temperatures. This avoids the high temperature conditions that would otherwise cause the hydrocarbon chains to crack or create coke. The vapor generated during this vacuum distillation stage is condensed to form a fuel similar to home heating fuel, VGO. This fuel is either used as fuel at the re-refinery or sold as an on-specification used oil fuel.

Vacuum Flash Tower/Thin Film Evaporation

In a third distillation vacuum tower, the VGO is subjected to high temperatures and low pressures, vaporizing the lighter lube oil fraction. A set of wiper blades spread the heavier oil against the wall of the heat exchange vessel in a thin film to help this material evaporate. The vapor is condensed and collected as used lube oil. A special high-temperature heat transfer fluid is used inside the heat exchanger. Two grades of lube oil are generally produced in this third distillation stage. One is a base stock with molecules containing contaminants such as sulfur, oxygen, and nitrogen, as well as those that have less favorable molecular structure such as olefins and aromatics. The other is a higher quality base stock product. Any material that does not evaporate in the evaporators is recovered and sold as an asphalt extender material for use in refining and asphalt paving.

Hydrotreating

The lower quality base stock molecules separated in the previous process are upgraded in the final stage of the process. This process more fully saturates the molecules and removes molecular contaminants from the oil, thereby improving its quality. This step uses hydrogen gas in a high-temperature, high-pressure, catalyzed reaction to remove remaining sulfur, chlorine, oxygen, and other impurities from the oil and improve product stability, color, and odor. The lube oil produced during this process is considered lubricant base stock. Subsequent blending of a variety of additives will produce motor oil, transmission fluid, hydraulic fluid, etc.

Acid Clay Treatment

In the acid clay process, after pretreatment to remove solids and water, the used oil is mixed with sulfuric acid to extract metal salts, acids, aromatics, asphaltenes, and other impurities. This process precipitates an acidic sludge that settles out of the oil. The remaining slightly acidic oil is mixed with clay (typically attapulgite or bentonite) to absorb other contaminants and to improve color. This process involves approximately 0.4 lb. of clay per gallon of oil. The clay is then filtered from the oil, and the acid content is neutralized prior to distillation. Acid clay treatment was the predominant technology in the past, but it is not often used today due to the hazardous waste produced by the process.

Clay Treatment

Clay treatment is sometimes used as a finishing step for distillate produced from vacuum distillation. There are two basic methods of clay treatment: (1) lube distillate is fed through static beds of clay at elevated temperatures, or (2) lube distillate is mixed with clay and kept in suspension in a heated reactor vessel and then filtered to remove the clay. For the clay to effectively treat the oil, it needs to be activated by heating. The clays can be regenerated and used multiple times before disposal. Clay treatment improves color and odor and removes some sulfur. The finished product meets API Group I base stock specifications, but it does not remove the unsaturated compounds to meet API Group II specifications. Clay treatment is perhaps better suited for smaller plants due to its lower capital investment requirements.

Solvent Extraction

This process is sometimes used to improve the quality of lube distillate produced from a vacuum distillation process. A solvent is used to extract polar compounds, aromatics, and lubricant additives, and then to increase saturate levels. One drawback is that the process removes unsaturated compounds, reducing the overall yield. This is in contrast to hydrotreating, which converts these compounds and maintains yield. Solvent extraction produces API Group I base stock that meets motor oil specifications but does not meet API Group II specifications due to its inability to remove sulfur.

Appendix C – Used Oil Sector Stakeholders Background Information

This appendix includes the following topics for additional information on pertinent aspects of the used oil business.

- Further details related to the generator stakeholder group.
- Details related to the oil processing and re-refining stakeholder group.
- A schematic of relative energy use and environmental impacts of used oil re-use options.
- Additional details on the quantification of oil losses in use.
- Additional details on the characteristics of used oil.
- Additional details on the space heater industry and the use of used oil as fuel for space heaters by used oil generators.
- A history of the U.S. used motor oil re-refining industry.

Background for Used Oil Generators

DIY Oil Change Group

A significant challenge from a used oil management point of view is to maximize recycling of used oil resulting from DIY operations. The 2006 report noted an API estimate that more than 80 percent of DIY oil change activities resulted in improper disposal of the used oil. It is likely that behaviors have improved since then due to an increase in the number and distribution of recycling locations and the general growth in environmental consciousness on the part of consumers, which is largely driven by more expansive outreach by government and non-governmental organizations (NGO).

Regardless of the convenience of collection options provided, there is a certain segment of the consuming public that changes its own oil and is not convinced that the small amount of oil they dispose of improperly (e.g., pouring down drains or sending to landfills via their garbage cans) is significant enough to cause serious harm to the environment.

Changing consumer recycling habits is a long-term activity that requires frequent reinforcement from educational and awareness programs. There are encouraging signs of progress in this area, but it will require continued effort.

DIFM Oil Change Group

Aside from the convenience that DIFM outlets provide their customers in terms of oil change services, in nearly all States, the DIFM operators serve an important role in that they collect DIY used oils for subsequent collection. It is not a risk-free operation because providing the freedom for DIYers to drop off their oil can open the door to unintended or illegal dumping of contaminants (e.g., PCB-contaminated oil) into the used oil collection tank. The risk in this operation is that if contamination is detected by a collector, it could deem the receipt tank as being hazardous waste, which requires incineration in a licensed incinerator at a minimum cost of $3.50 per gallon, plus the costs of transport and remediation of the collection tank.[209] As typical tank sizes range from several hundred gallons up to 3,000 gallons, the cost penalty to a DIFM operation can easily range from several thousand dollars to several tens of thousands of dollars per incident. The average quick lube operator generates monthly revenue from zero to a few hundred dollars from used oil sales, so this can easily represent several months of revenue.

Today, industry analysts indicate that essentially 100 percent of the used oil that is collected at DIFM sites is recycled. A portion is recycled to internal heating purposes in space heaters, and the balance is sold to collectors (or delivered to collectors for a fee as in 2016–2017). One very encouraging sign of progress is that there is a growing trend toward DIFM oil changes on the part of the consuming public.

There is concern that as lube oil technology evolves and drain intervals grow, this may have a negative impact on the DIFM operators. As profit margins decrease, it is possible that DIFMs' willingness to accept DIY used oils may be reduced. If DIY consumers find that their drop off points are no longer convenient or willing to accept their used oil, the volumes of used oil that are improperly disposed may grow. Another issue for DIFM operators relates to liability for oil collected from DIFM locations. As mentioned earlier in the report, due to legislative delays, quick-lube operators can be held liable for oil stored at third-party, used oil recycling-turned-Superfund sites, of which, there are 62 known sites across 26 states. While some of the oldest ones should be closed by now, such sites can take decades to "discover" despite the fact that these recycling facilities were licensed and should have been routinely inspected, thereby eliminating any opportunity for them to become Superfund sites. When such sites are identified, the quick-lube operators whose used oil was collected and then improperly handled at the site must bear the costs. The Beede Waste Oil Superfund site in New Hampshire is a prime example.[210]

Another issue related to these sites (two of which operated until 2010) and others that may yet appear is that (a) private potentially responsible party groups often form at these sites and may try to wear down otherwise exempt parties with transaction costs; and (b) State law, as in California, can arguably negate CERCLA exemptions. One solution to preventing this from happening in the future would be for EPA and every State and local government that has jurisdiction over used oil recycling facilities to provide routine onsite inspections and to encourage recyclers to participate in voluntary compliance auditing so that the used oil generator and transporter community can identify the most responsible used oil recyclers.

Handling Oil Filters

Another important aspect of the used oil generation business is to ensure that oil filters are included in the context of recycling programs. Oil filters can contain from to 4 to 11 ounces of

[209]Coles, D.G., 2016, "PCB Infiltration into the Used Oil Recycling System: Causes, Costs, and Corrective Actions," a report to the U.S. Environmental Protection Agency, prepared for NORA, *available at* https://cdn.ymaws.com/www.noranews.org/resource/resmgr/TSCA_Reform_Effort/NORA_PCB_Rept_4-6-16.pdf.
[210] Evans-Brown, S., 2013, "As Water Cleanup Commences, Beede Story Shows Superfund Law's Flaws," *available at* https://www.nhpr.org/post/water-cleanup-commences-beede-story-shows-superfund-laws-flaws#stream/0.

used oil and, if not properly handled, represent a missed opportunity for used oil recycling. Collecting and recycling oil filters can help avoid polluting landfills. The 2006 report noted that the Filter Council reported recycling rates of nearly 50 percent.

The EPA's 40 CFR identifies non-terne plated[211] used oil filters as non-hazardous wastes if they have been "hot drained" or otherwise processed to remove any remaining oil. Hot draining entails removing the filter from the engine while it is still at engine temperature (or at least 60°F), perforating the dome end of the filter, and suspending the filter dome end down over a container to allow the filter to drain a minimum of 12 hours. After this has been accomplished, the oil is recycled, and the filter can be recycled as scrap metal or disposed of in a landfill. Proper recycling of the oil filters sold annually in the United States could result in the recovery of about 160,000 tons of steel.[212]

DIFMs may or may not accept used filters from DIYs, as these entail some cost to process for recycling. Although many States require that used oil filters be drained for a period of 12–24 hours, uninformed garage or DIFM shop operators can find the process too time consuming and gravity-drain the oil filters for only a few minutes before discarding them into the trash. Because a large percentage of the oil could still remain in an improperly drained filter, it is considered hazardous waste. Shop operators can be fined for improper or illegal hazardous waste management if they dispose of oil filters that have not been properly drained.

Some shops may utilize an oil filter crusher that presses the filter under high pressure and squeezes the oil out. The device reduces used filters to 25 percent of their original size—about the size of a hockey puck. The end result is a collection drum filled with recyclable metal "pucks" that comply with EPA disposal guidelines. Because most collection companies charge a collection and hauling fee for each drum, fitting more recycled filters into each drum saves money. Garages and DIFM shops that recycle both the used oil removed from the filter and the filter casing as scrap metal are exempt from hazardous waste regulations and do not need to test their filters to determine whether they are hazardous.

[211] Terne is a mixture of tin and lead historically used for plating sheet steel to inhibit corrosion. Terne was replaced as a plating material with Terne II that uses zinc in place of lead.
[212] https://www.steelsustainability.org/-/media/recycling-resources/recycling-used-oil-filters-shop.ashx.

Background for Used Oil Processors and Re-Refiners
Processing of Used Oil from Industrial Oil Sources

Industrial oils are managed more carefully than consumer automotive used oils and, consequently, a higher percentage of these used oils are recycled. There are many forms of processing for industrial oils. Some high-volume treatment operations are performed directly at the customer's plant site where the oil is used; and, in other cases, it is trucked to a facility. In many cases, the oil is treated in a closed loop operation whereby the used oil is processed several times to protect the quality and then returned to the customer after the addition of additives to meet customer specifications. Such operations are referred to as “closed loop,” where lube oils can be recycled almost indefinitely. The number of cycles that can be achieved is a function of the severity of the application. This “closed loop” recycling process offers the customer the maximum amount of quality security and also provides some protection against the impacts of high crude oil prices.

A key difference in processing used oil to produce automotive oils versus industrial oils and fuels is energy input and processing severity. A more severe process is needed to produce base stock for automotive use, while industrial oil processing is less severe.

Re-Refined Base Stock Quality

Re-refiners produce a base stock that can be used in the production of motor oils and industrial oils comparable to virgin base stocks. The lube oils used to blend motor oil meet API certification and International Lubricant Standardization and Approval Committee (ILSAC) standards. These can be advertised and displayed on product packaging by showing API's motor oil quality marks—the API Service Symbol "Donut" and Certification Mark "Starburst" which help consumers identify quality motor oils for their gasoline and diesel-powered vehicles.

Flow Schematic Showing Used Oil End Use Options

Figure C-1 presents a simplified schematic that details the major used oil flows and how the stakeholders interact with each other. Specifically, it shows how motor oils and industrial oils are handled once they are collected as used oils.

Motor oils are sold either to DIY or DIFM channels. DIY oils can be gathered by collectors or improperly disposed of in landfills. DIFM oil is gathered and then either burned as a fuel or transferred to re-refining operations. From there, the regenerated oil is either burned or sold as base stock for fresh motor oil or industrial oil blending.

Industrial oils generally follow the same path as motor oils, but they do not flow through the DIY and DIFM operations, they are handled more directly by processors or reclaimers where the industrial oils are cleansed either for fuel applications or for fresh new industrial oil blending. Rarely would industrial oils end up being processed into new motor oil components.
Both oils have some portion that is consumed in operation, which is unavailable for recycling or regeneration.

Oil Losses in Use

One of the difficulties involved in accurately assessing total used oil volumes and the overall efficiency of used oil recycling is that a significant portion of lubricating oil is consumed during use and is never made available for recycling. Quantifying this volume is difficult due to the large number of factors involved and the lack of available data to quantify individual losses.

Vehicle Motor Oil

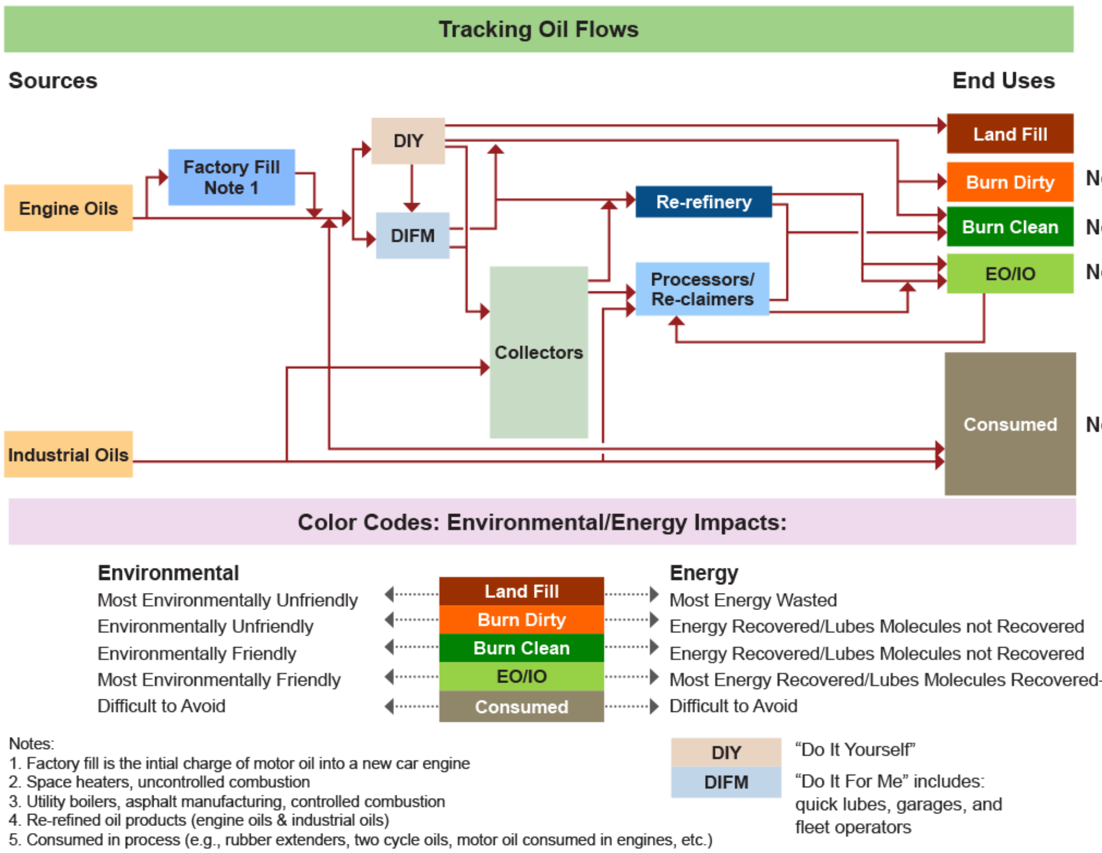
In 2018, U.S. vehicles traveled 3.21 trillion miles per year.[213] Since 2007, vehicle miles traveled (VMT) in the United States flattened at about 3.0 trillion miles, largely because of the economic recession. However, since 2015, VMT has risen as the U.S. economy has recovered, and petroleum prices have remained relatively low. A consumption level of 1 quart every 1,500 miles is not considered unacceptable for a high mileage engine.[214] However, most new engines today use less than half a quart of oil in 3,000 to 5,000 miles.[215] Some consume almost no oil. So, considering only these estimates, it is easy to see that the range of values for oil lost in use for U.S. vehicles of all types could range from 80 MMG to more than 500 MMG each year.

Other Engine Oils

Another type of motor lubricant that is not recoverable is two-cycle motor oils that are designed to be combusted with the primary fuel. In a two-stroke engine, the oil is typically mixed with the fuel, usually somewhere in a 50:1 to 20:1 range. With a four-cycle automobile engine, the lubricating oil is injected from a separate reservoir (the crankcase). Two-cycle engines are no longer used for vehicles but are used for outboard motors for smaller watercraft, dirt bike and moped engines, and a variety of lawn care and hand utilized maintenance equipment (e.g., lawnmowers, leaf blowers, trimmers, chainsaws, etc.).

[213] DOE, *available at* https://afdc.energy.gov/data/10315.
[214] https://www.bellperformance.com/blog/when-is-oil-consumption-considered-excessive.
[215] https://www.aa1car.com/library/oil_consumption.htm.

Figure C-1. Used Oil Flow Diagram



Industrial Oils

A number of industrial oils are not recovered but are consumed in processing; for example, oils used to lubricate food processing equipment; white oils used as protective coating for fruits and vegetables; oils sprayed for dust control of grain; de-foaming agents; pharmaceutical and cosmetic products (e.g., baby oils and skin, hair, and facial products); oil components of printing inks; textile processing lubricating oils; chemical carrier oils; friction lube oils (e.g., wire rope lube oils, chain oils, chain saw oil, arbor oil); some refrigeration oils; metal machining oils (e.g., drilling, tapping, boring, milling, grinding, tapping, sawing, and shaping); metal forming oils (e.g., drawing, ironing, rolling, forging, and stamping); surface protection oils (e.g., corrosion inhibitors); metallurgical process oils (e.g., steel and metal quenching and tempering); dust suppressants; agricultural chemical spray oils; and rubber and plastic production oils (e.g., plasticizers, extender oils, and mold release oils).

Characteristics of Used Oils

Re-refining used oil is complicated by the fact that used oil is difficult to characterize. Its character is very much dependent upon the source of the used oil (motor oil, industrial oil) and also, to some degree, how it was collected (i.e., what was mixed with it in collection tanks). The variable character of used oils drives the complexity of the facilities necessary to treat it for re-use. High tech motor oil, for example, contains as much as 20–25 percent additive components in the finished product. In addition to the original base stocks and additives, used oils contain water, non-combustible ash, heavy metal compounds, sulfur, and solids such as dirt and grit from blow-by carbon in diesel engines. Water can exist as free water or in emulsified form as a result of the chemical additives in motor oils that are designed to prevent free water from accumulating in engine reservoirs. Heavy metals come from certain additives and from the engine itself, while sulfur is an important part of anti-wear and detergent additives. Finally, used oils can also contain solvents (including chlorinated solvents), PCBs, and other extraneous materials that may require special handling by the processor or re-refiner should the percentage of these components become too high.

PCBs range in consistency from an oil to a waxy solid and belong to a broad family of man-made organic chemicals known as chlorinated hydrocarbons. PCBs were domestically manufactured from 1929, until manufacturing was banned in 1979. They have a range of toxicity and vary in consistency from thin, light-colored liquids, to yellow or black waxy solids.[216] Due to their non-flammability, chemical stability, high boiling point, and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications. PCBs can be introduced into used oil collection containers from vintage sources such as hydraulic fluids (mostly from high-temperature applications such as die-casting machines), electrical equipment (transformer oil, voltage regulators, switches, etc.), heat transfer equipment, and older oil-based paints.

Transformer Oils

Utilities use large step-up transformers to increase voltage to push electricity more efficiently through long-distance transmission lines—hence the term "high tension wires." Utilities also use smaller step-down transformers to reduce voltage to the relatively safe 120/220 volts AC residential power. There are millions of transformers in use across the United States and globally.[217] Transformer oil, also known as insulating oil, is commonly used in transformers for its excellent electrical insulating and dielectric properties. Transformer oil is also used in high voltage switches, high voltage capacitors, and circuit breakers. The primary function of the transformer oil is to insulate and cool down the transformers. The transformer oil acts as a coolant agent to dissipate the heat of the transformers. Each year, millions of gallons of transformer oil reach their life end and usually become unfit for further use because of accumulated contaminants and the loss of electrical, chemical, and physical performance.[218, 219]

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216 EPA, *available at* https://www.epa.gov/pcbs/learn-about-polychlorinated-biphenyls-pcbs.
217 https://www.hazardouswasteexperts.com/hazardous-waste-removal-electrical-transformer-end-of-life/.
218 https://www.industrialsurplusworld.com/transformer-oil-disposal.
219 https://www.hydrodec.com/our-business/north-america/used-oil-collection-and-treatment.

PCBs were used in many industrial and commercial applications, including transformer oil, in many countries. Transformer oil is a contaminant if spilled and not recycled properly, especially if the oil contains PCBs. The older transformers usually carry PCBs, but the oil must be tested to determine which regulations apply to its disposal. If the oil contains PCBs, using advanced technology, it is possible to treat transformer oil and recycle it. Recycling transformer oil avoids emissions because the waste oil is typically incinerated to destroy its toxic contaminants. Uncontrolled burning of PCBs generates dioxins and furans at potentially unsafe levels and is strictly prohibited by the TSCA PCB regulations—see 40 CFR 761.50(a)(1). EPA does not approve incinerators that present an unreasonable risk of injury to health or the environment, including through the production of byproducts like dioxins and furans. Prior to approving a PCB incinerator, the facility must conduct a trial burn with stack sampling to detect any dioxins or furans that may be produced.

Collecting, recycling, and disposing of transformer oil must be handled by licensed companies. Critical to the successful disposal of all used oil, including both lubricating and transformer oil, is total clarity over the final destination of such used oil. Concerns have been raised by some in industry that tighter oversight would eliminate inefficiently monitored export routes to and from other countries for use, among other things, as a diesel extender. A suggestion by Hydrodec of North America, LLC, a participant of the October 16, 2019 public meeting, was that where the technology and re-refining capacity exists in the United States, re-use of transformer oil should be mandatory. At the very least, it should be encouraged as a 'best practice,' which would keep products in the consumption sphere for a longer period. A suggestion made was to require utilities to produce 'Certificates of Origin' (Non-Hazardous Manifest)—documents that certify the destination of all used transformer oil—to ensure best environmental practice and the end of unnecessary incineration.

The Space Heater Industry and the Use of Used Oil by Generators as Fuel for Space Heating

Industry Overview

Used oil fired space heaters have been part of used oil management in the United States for over four decades. The space heater industry estimates that there are about 100,000 U.S. businesses that are actively using space heaters.

The used oil space heater industry manufactures and sells space heaters and small boilers that are designed to meet the requirements of 40 CFR Part 279 and utilize Underwriters Laboratories (UL) rating for standards and testing methods (UL 296). In addition, a number of States provide tax credits for generators to install space heating units (Kentucky, Arizona, Connecticut, Virginia, Arkansas, and Montana). Per 40 CFR Part 279, units have a maximum capacity of no more than 0.5 million Btu per hour and are vented to the ambient outside atmosphere. Oil is stored in a tank adjacent to the unit and is pumped to the space heater or small boiler.

Currently, across North America, over 6,000 new space heaters are sold and installed annually through six major brands (Clean Burn, Lanair Products, Clean Energy Systems, Energy Logic, Reznor, and Firelake). Each of these companies is also a small business as defined by the Small Business Administration. The supporting network of U.S. dealers and distributors include approximately 80 other small businesses. Along with the manufacturers, the industry employs over 1,000 people. In addition, thousands of additional people are supported as vendors and channel partners.[220]

The 100,000 installations are typically small businesses operating in small shop spaces (e.g., auto dealers, auto repair shops, farms, construction equipment repair shops, municipal government maintenance shops, and truck stops). Many of these enterprises not only generate used oils but also provide collection locations for DIY used oil collection. The value proposition for these businesses is their ability to use a waste generated by their business (used oil) as a fuel to heat their shop. The heaters displace the need to use other fuels such as electricity or natural gas.

Oil burning space heaters are found in all regions of the United States, with their distribution roughly aligned with population density, although with perhaps a few more per capita in the Northeast and Midwest as might be expected (Table C-1).

Table C-1. Estimated Space Heater Installation Distribution

<table>
<tr><th>Region</th><th>Population [221]</th><th>Estimated Share of Space Heater Installations [222]</th></tr>
<tr><td>Northeast</td><td>17.2%</td><td>20.7%</td></tr>
<tr><td>Midwest</td><td>20.9%</td><td>23.9%</td></tr>
<tr><td>Mountain and Southwest</td><td rowspan="2">23.8%</td><td>6.4%</td></tr>
<tr><td>Pacific Northwest</td><td>15.8%</td></tr>
<tr><td>Southeast</td><td rowspan="2">38.1%</td><td>11.7%</td></tr>
<tr><td>Middle Atlantic</td><td>21.6%</td></tr>
</table>

[220] A channel partner is a company that partners with a manufacturer or producer to market and sell the manufacturer's products. This is usually done through a co-branding relationship.
[221] U.S. Census, *available at* https://www.census.gov/popclock/print.php?component=growth&image=//www.census.gov/popclock/share/images/growth_1530403200.png.
[222] Information provided to DOE by Rock Energy Systems, LLC, October 2019.

Space Heater Safety and Emissions

Each time EPA takes up the subject of used oil, it comes to the conclusion that the ability to combust used oil for energy recovery via space heaters provides incentives for small business to properly dispose of their used oil. In 1994, EPA undertook a study of the use of waste oil heaters, "Vermont Used Oil Analysis and Waste Oil Furnace Emissions Study,"[223] and concluded that waste oil heaters are environmentally friendly in that they eliminate the risk of consumers dumping the oil. In addition, the safety of used oil when used in space heaters and small boilers was supported by a March 1996 study by the Vermont Agency of Natural Resources. This study concluded that the combustion of used oil in air atomizing space heaters complies with Vermont Air Pollution Control Regulations. Risks posed by using used oil in appropriately vented space heaters will be even less today given the fact that the used motor oil being generated today is much cleaner than used motor oils generated in the past, in large part due to the elimination of leaded gasoline and the reduction in sulfur content of diesel fuel, resulting in less ash in the crankcase oil.

Modern used oil burners incorporate several features to allow them to burn cleanly and efficiently. The oil is filtered to remove large particles. Then, it is preheated to reduce its viscosity. The heated oil then flows into an air-blast atomizing nozzle, which uses compressed air to spray the oil out as tiny droplets. The droplets are ignited electronically by a large continuous spark, and the flame is stabilized by a flame retention head. The units are equipped with multiple safety features, such as flame-out sensors, fuel shutoff valves, and temperature limit controls.

In 2007, an independent, third-party test company conducted an air emissions test of an Energy Logic EL-340H furnace burning waste crankcase oil. The results are summarized in Table C-2 and compared with estimates for heavy-duty trucks based on EPA's allowable levels for several model years. The results show that the oil burns completely in the furnace, as the unburned hydrocarbons and the carbon monoxide (CO) are very low. The higher level of sulfur dioxide (SO_2) is due to sulfated ash used as an additive in motor oil.

Additional EPA testing was done on a Clean Burn brand furnace, independent of the above tests, by the Clean Burn company (Table C-3). While actual results on specific heaters using specific used oils will vary, these results provide a general guide of the emissions expected from such furnaces.

[223] EPA, 1994, "Vermont Used Oil Analysis and Waste Oil Furnace Emissions Study," *available at* https://www3.epa.gov/ttn/catc/dir1/w_oilacr.pdf.

Table C-2. Emissions Data from Tests Comparing Space Heater With Heavy Duty Truck Exhaust Emissions [224]

Group	EL-340H Used Oil Furnace Emissions (lb. / hr.)	1998 EPA Truck Emissions (lb. / hr.)	2007 EPA Truck Emissions (lb. / hr.)	2010 EPA Truck Emissions (lb. / hr.)
Total Particulates	0.097	0.14	0.014	0.014
Total Hydrocarbons	0.004	1.86	0.20	0.20
SO_2	0.101	0.0008	0.0008	0.0008
NO_x	0.052	5.73	1.72	0.29
CO	0.010	22.21	22.21	22.21
CO_2	54	78	78	78

Table C-3. Emissions Data from Tests on Space Heater Combustion Stack

Oil Constituent	EPA 40 CFR 279.11 Allowable Level	Test Results
Arsenic	5 ppm max	No detectable
Cadmium	2 ppm max	No detectable
Chromium	10 ppm max	3.19 ppm
Lead	100 ppm max	47.23 ppm
Flash Point	100 degrees F min	>200 degrees F
Total Halogens	4,000 ppm max	< 350 ppm

Flue Constituent	Stack Reading	Comments
NO_x	112 ppm	Corrected to 3% O_2
CO	20 ppm	-
Smoke Test	1 Spot	-

EPA has decided that on-spec used oil is similar in composition to virgin fuel oil and should continue to be managed as a fuel rather than as a waste. The vast majority of used oil combusted in space heaters is on-spec oil. However, EPA recognized (in Section 40 CFR 241) the importance of combusting used oils and also exempted the burning of off-spec oil in space heaters that meet the requirements of 40 CFR 279. EPA recognized that the majority of the users of space heaters were small businesses and DIY oil collectors, and these small businesses derive significant economic benefit from their ability to continue to burn used oil for energy recovery. The EPA decision reflected the fact that in the absence of their ability to burn used oil for energy

[224] Information provided to DOE by Rock Energy Systems, LLC, October 2019.

recovery, these oil generators would be more likely to be motivated to illegally dispose of such oil.

The used oil space heater industry provides small business used oil generators with an alternative to the passing along of used oil to collectors for processing or re-refining. The industry is small but significant to its partners and customers. It provides an EPA-approved alternative for thousands of small businesses to dispose of their used oil.

Estimates of Used Oil Burning by Space Heaters

Space heater manufacturing industry stakeholders estimate that based on 100,000 active heaters and an assumed 800–1,200 gallons of oil combusted per year by the average heater, the volume of combusted used oil ranges from 80–120 MMG per year.[225] These estimates are based on discussions with customers about the volume of used oil they generate each year, space heater unit in-use times recorded for maintenance purposes (the average usage in a heating season ranges from 700–800 hours), and known unit burn rates (an average of 1–1.5 gallons per hour, depending on heater size).

The potential cost savings from using used oil as fuel for space heating can be considerable. Table C-4 provides some rough estimates, assuming an average of 100 MMG per year of 140,000 Btu per gallon of used oil is burned by 100,000 units. The estimates show that, depending on the fuel being displaced, burning used oil can save a business between $1,171 and $4,526 per year in fuel costs. As space heaters cost between $5,000 and $15,000, with the average in the range of $8,000, the investment can pay out in only a few years.[226]

[225] Information provided to DOE by Rock Energy Systems, LLC, October 2019.
[226] *Ibid.*

Table C-4. Estimates of Cost Savings by Generators Displacing Fuel through Burning of Used Oil in Space Heaters

	Natural Gas	Electricity	No. 2 Heating Oil
Waste Oil Energy Content (Btu / gallon)	140,000	140,000	140,000
Waste Oil Burned (MMG per year)	100	100	100
Waste Oil Energy Captured (Trillion Btu per year)	14	14	14
Price	$8.49 / Mcf	$0.11 / kW-hr	$3.22 / gallon
Purchased Fuel Energy Content	1,015 MBtu / Mcf	3,412 Btu / kW-hr	140,000 Btu / gallon
Fuel Displaced per year (assuming 100% of generators displacing each fuel)	13.79 Billion cubic feet	4,103 Million kW-hr	100 Million gallons per year
Share of generators displacing this fuel (%)	65%	10%	25%
Total Fuel Cost Savings (Million $)	$76.12	$45.26	$80.50
Annual Fuel Cost Savings per unit	$1,171	$4,526	$3,220

Appendix D – Highlights of Key Federal Statutes and Regulations that Relate to Management of Used Oil

The specific regulations that deal with used oil management include the following:

- Resource Conservation and Recovery Act (RCRA) Used Oil Management Standards
- Toxic Substances Control Act (TSCA)
- Clean Air Act (CAA) National Emission Standards for Hazardous Air Pollutants (NESHAP)
- Clean Air Act Offsite Waste Rule
- Clean Water Act Centralized Waste Treatment (CWT) Point Source Category
- Spill Prevention Control and Countermeasures (SPCC) plan requirements
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- Emergency Planning and Community Right to Know Act (EPCRA)
- Nuclear Regulatory Commission used oil regulations
- Coast Guard used oil regulations dealing with releases of used oil to navigable waters and shipboard management of used oil
- Hazardous Materials Transportation Act (HMTA)

Highlights of these regulations are provided below.

1. Resource Conservation and Recovery Act (RCRA) Used Oil Management Standards (40 CFR Part 279, UOMS) are intended to protect soil, groundwater, surface water, and air. UOMS prohibit storing used oil in units other than good condition tanks and containers unless the other unit has a RCRA permit, and they allow mixture with hazardous wastes under limited conditions. UOMS require used oil generators, with a few exceptions, to use only tanks and containers that are in good condition; label used oil tanks and containers; respond to releases; and use a transporter with an EPA ID number. In addition to the generator requirements, used oil transporters are required to notify the EPA or authorized State Government of their used oil activities, if the transporter does not already have an EPA ID number, to determine total halogen concentration and to maintain tracking records. Used oil processors/re-refiners are obligated to comply with the previously mentioned requirements to prepare a used oil contingency plan (an SPCC plan may be modified rather than preparing a unique plan for the UOMS) and to maintain secondary containment, a used oil analysis plan, recordkeeping, and biennial reporting.

Used oil marketers must also be generators, transporters, or processor/re-refiners and have tracking requirements for both on-spec and off-spec used oil fuel; the first person to claim that used oil meets the specifications must maintain documentation to support the claim. Used oil burners include industrial boilers, utility boilers, and industrial furnaces (e.g., cement kilns, asphalt aggregate dryers, blast furnaces, coke ovens, smelters). Used oil generators are also allowed to burn household used oil and used oil generated on-site for energy recovery in a used oil-fired space heater with a capacity less than 500,000 Btu/hour that is vented to the ambient air. All but two States (Alaska and Iowa) have achieved base program authorization for RCRA State

Hazardous Waste Programs and are required to have standards for used oil management, which are equivalent to 40 CFR Part 279 (40 CFR 271.26). Aside from the UOMS, RCRA Subtitle C more rigorously regulates used oil destined for disposal that is a solid and hazardous waste. RCRA Subtitle I imposes management standards on underground storage tanks. Subtitle D of RCRA provides minimum standards for States to achieve Federal authorization for solid waste disposal.

2. Toxic Substances Control Act (TSCA) PCB regulations (40 CFR Part 761) prohibit the distribution in commerce of equipment containing oils with PCB concentrations above 500 ppm, the dilution of the PCB concentration to avoid regulation, and the manufacture of PCB-containing equipment generally. Oil used in high-temperature hydraulic fluid and electrical equipment may contain PCBs due to historic use of PCBs as a fire retardant. PCB-containing equipment is still in use. Used oil containing PCBs between detection and 50 ppm is regulated by TSCA, which references RCRA UOMS when burned for energy recovery. A TSCA rule restricts the on-site burning of used oil (containing detectable PCBs) in space heaters to the automotive industry.

3. Clean Air Act (CAA) National Emission Standards for Hazardous Air Pollutants (NESHAP) rules for Off-site Waste Recovery Operations [40 CFR 63, Subpart DD or Off-Site Waste and Recovery Operations (OSWRO) NESHAP] apply to used oil processors/re-refiners as defined in the RCRA UOMS if the facility on which the processor/re-refiner is located is a major source of hazardous air pollutants. A major source means any stationary source (or group of stationary sources within a contiguous area and under common control) that emits or has the potential to emit—considering controls, in aggregate—10 tons or more per year of any hazardous air pollutant (HAP) or 25 tons per year or more of any combination of HAPs. OSWRO NESHAP regulated sources include tanks, surface impoundments, containers, oil/water and chemical/water separators, material transfer systems, process vents, and equipment leaks. Some used oil combustion units are located at major source facilities and would be subject to Title V permit requirements. Off-specification fuel oil combustion can result in CISWI (Commercial and Industrial Solid Waste Incineration rule) applicability to the boiler or cement kiln. Potential CISWI applicability and limitations to the types of units that may burn certain off-specification used oils (Non-hazardous Secondary Material rule) are Federal rules that should be considered for off-specification used oil combustion.

4. Clean Air Act Offsite Waste Facilities Rule includes hazardous waste treatment, storage, and disposal facilities; industrial wastewater treatment facilities; solvent recycling facilities; and used-oil recovery facilities that manage hazardous air pollutant-containing materials generated at other facilities. A number of toxic air pollutants (including chloroform, toluene, formaldehyde, and xylene) are released from tanks, process vents, equipment leaks, containers, surface impoundments, and transfer systems at these facilities. EPA's rule combines equipment, operations, and work practice standards. For example, the rule requires that containers be covered and that process vents meet 95 percent organic emission controls. The rule affects an estimated 250 off-site waste operation facilities. It will reduce air toxics emissions by 43,000 tons per year and VOC emissions by 52,000 tons per year.

5. Clean Water Act Centralized Waste Treatment (CWT) Point Source Category (40 CFR 437) and Test Procedures for the Analysis of Pollutants (40 CFR 136) apply to facilities that accept waste from off-site, that treat and/or recover these wastes, and whose activities generate a wastewater. More specifically, recycle/recovery activities are covered by the rule unless specifically exempted. Fuel blenders that generate wastewater are regulated by this rule. All re-refiners are regulated by this rule. Many RCRA UOMS processor/re-refiners are regulated by the CWT rule's oil subcategory. The CWT rule imposes best practicable control technology currently available for 3 conventional pollutants, 13 metal pollutants, and 6 organic pollutants. The CWT rule is intended to protect the public health or welfare, including, but not limited to, fish, shellfish, wildlife, shorelines, and beaches.

6. The Spill Prevention Control and Countermeasures plan requirements (SPCC, 40 CFR 112) originate in the Clean Water Act, as amended. SPCC plans are intended to protect surface waters from releases of oil, including vegetable oil, animal oil, and used oil, to navigable waters. SPCC rules in effect apply to (1) non-transportation-related facilities; (2) facilities with an aboveground storage tank capacity greater than 660 gallons in a single container, an aggregate storage capacity greater than 1,320 gallons, or a total underground capacity greater than 42,000 gallons; and (3) facilities where there is a reasonable expectation of a discharge to navigable waters or adjoining shorelines of the United States. Pathways to navigable waters include street gutters and sewers that discharge to surface water. SPCC plans should address operating procedures the facility implements to prevent oil spills, control measures installed to prevent a spill from entering navigable waters or adjoining shorelines, and countermeasures to contain, cleanup, and mitigate the effects of an oil spill. The requirements include a professional engineer's certification, spill predictions, facility drainage, facility inspections, site security, three-year plan review, management approval, oil spill history, secondary containment or diversionary structures, loading/ unloading rack area for tank car and tank trucks, and training and spill briefings.

7. The Comprehensive Environmental Response, Compensation, and Liability Act, as amended, contains many used oil-related provisions. Emergency removal and site remediation authorities for 'hazardous substances' have been applied to abandoned used oil sites. The service station dealer exemption from potentially responsible party liability in Section 114 of CERCLA provides an incentive for service station dealers to accept used oil generated by households and to comply with the RCRA UOMS. CERCLA defines the term 'hazardous substance' in Section 101(14) as including non-oil hazardous substances designated pursuant to 1321(b)(2)(A) of the Federal Water Pollution Control Act (FWPCA); any element, compound, mixture, solution, or substance designated pursuant to Section 9602 of CERCLA; any hazardous waste identified pursuant to Section 3001 of the Solid Waste Disposal Act (RCRA); the toxic pollutant list as identified in Section 1317(a) of the Water Pollution Control Act; hazardous air pollutants listed under Section 112 of the Clean Air Act; and any imminently hazardous chemical substance or mixture subject to an action under Section 2006 of Title 15. While the term 'hazardous substance' does not include petroleum crude oil or a fraction of petroleum crude oil, natural gas, natural gas liquids, liquefied natural gas, or synthetic gas useable for fuel, it does include oil that has been contaminated with impurities through use. Therefore, requirements applicable to 'hazardous substances' also apply to 'used oil,' such as notifying the National Response Center upon release to the environment.

8. The Emergency Planning and Community Right to Know Act includes Toxic Release Inventory reporting requirements and notifying the local emergency planning committee of hazardous materials stored on-site. Hazardous materials are those for which the Occupational Health and Safety Administration requires a material safety and data sheet (MSDS) pursuant to its risk communication standard at 49 CFR 1910. Chlorinated ethanes (i.e., paraffins) and chlorinated naphthenes, both of which have been lubricant additives and found in used oil, are on the list. Also, cresols are listed, and one type of cresol may be present as a biocide in oil products. The 'list of lists' for EPCRA is available on EPA's website at the following link: http://www.epa.gov/ceppo/pubs/title3.pdf.

9. The Nuclear Regulatory Commission promulgated a final rule addressing the management of used oil mixed waste. On-site incineration of contaminated waste oils generated at licensed nuclear power plants is allowed without amending existing operating licenses. Compliance with other applicable Commission regulations (e.g., effluent release limitations) is still required. See 57 FR 57649 - 57656, December 7, 1992.

10. Releases of used oil to navigable waters and shipboard management of used oil are regulated by the Coast Guard under the authority of the International Convention for the Prevention of Pollution by Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78) and subsequently revised in 1992. The 1992 revisions entered into force on January 1, 2007. MARPOL restricts the quantity, rate, and location of operational discharges of oil from tankers. An oil record book must be used to record the movement of cargo oil and its residues from loading to discharging on a tank-to-tank basis. Segregated ballast tanks are required on all new tankers of 20,000 dwt and above and are to be positioned in such a way that the cargo tanks are protected. The 1992 amendments to Annex I mandated double hulls for new oil tankers and created a phase-in schedule for existing tankers to fit double hulls.

11. The U.S. Department of Transportation (DOT) regulates the transportation of hazardous materials in commerce under the authority of the **Hazardous Materials Transportation Act (HMTA)** (40 CFR Parts 171 to 179). Used oil is classified as a hazardous material if it meets the definition of a combustible liquid (flash point greater than or equal to 100ºF and less than 200ºF) or flammable liquid (flash point below 100ºF). DOT regulations address identification and classification, packaging, marking, labeling, and shipping papers; and, for transporters, placarding, use of shipping papers, recordkeeping, reporting, and incident response.

Appendix E – Example of State Used Oil Management Legislation: California

This section contains links to the regulations in the State of California related to the management, transportation, and recycling of used oil. California has perhaps the most robust regulatory framework regarding used oil, as well as well-supported programs for its collection, which is why its regulatory language is presented as an example.

The relevant regulations related to California recycling enhancement can be found in the California Public Resources Code; Division 30: Waste Management; Part 7 – Other Provisions; Chapter 4 – California Oil Recycling Enhancement. There are 10 Articles in this Chapter, as listed below with links to the regulatory language on the JUSTIA US Law website.

- Article 1 – Legislative Findings: 48600
- Article 2 – Short Title: 48601
- Article 3 – Definitions: 48610-48625
- Article 4 – Used Oil recycling: 48630-48632
- Article 5 – Administration: 48640-48645
- Article 6 – Financial Provisions: 48650-48657
- Article 7 – Certification: 48660-48662
- Article 8 – Reporting: 48670-48676
- Article 9 – Enforcement: 48680
- Article 10 – Local used Oil Collection Program: 48690-48691

In addition to the information provided above, the related laws in California that deal with the classification and management of used oils as hazardous wastes (meeting or exceeding the minimum requirements of CFR Part 279) can be found in the 2018 California Code, Health and Safety Code, Division 20: Miscellaneous Health and Safety Provisions, Chapter 6.5 – Hazardous Waste Control, Article 13 - Management of Used Oil, Section 25250.
This can be found at the following URL: https://law.justia.com/codes/california/2018/code-hsc/division-20/chapter-6.5/article-13/

Appendix F – Results of Internet Search for State Used Oil Programs

State	State or locally (county or city) funded collection centers	Online recycling location list or search	Retailer collection	Intermittant collection programs	Required reporting on volumes of oil collected	Tax on lube oil oil sales to fund collection	State purchasing preferences for used oil derived lubricants	State rules for handling of used oil	State rules for disposal of used oil filters	State or local recycling of used filters	Rules for classifying used oil as hazardous waste	State regulations relative to Federal
Number of States in 2006 (2019)	32 (51)	30	42 (51)	11 (36)	19 (51)	9 (1)	24 (22)	12 (51)	3 (50)	8 (2)	51	16 State, 35 Federal
Alabama	Local	•	•		•			•	•		•	State
Alaska	Local		•		•		R	•	•		•	State
Arizona	Local	•	•		•		R	•	•		•	Adopted Fed+
Arkansas	Local	•	•		•			•	•		•	Adopted Fed+
California	State and Local	•	•	Some local	•	•	R, O	•	•	•	•	State
Colorado	Local		•	Some local	•			•	•		•	Adopted Fed+
Connecticut	Local		•		•		R	•	•		•	State
Delaware	State and Local	•	•		•			•	•		•	Adopted Fed+
District of Columbia	District		•		•			•	•		•	District
Florida	Local	•	•		•			•	•		•	State
Georgia	Local		•	Some local	•			•	•		•	Adopted Fed+
Hawaii	Local		•		•		R, O	•	•		•	Adopted Fed+
Idaho	Local		•		•			•	•		•	Adopted Fed+
Illinois	State and Local	•	•		•		R	•	•		•	Adopted Fed+
Indiana	State and Local	•	•	Some local	•			•	•		•	Adopted Fed+
Iowa	Local		•		•			•	•		•	Adopted Fed+
Kansas	Local	•	•		•			•	•		•	Adopted Fed+
Kentucky	Local		•	Some local	•		R	•	•		•	Adopted Fed+
Louisiana	Local		•	Some local	•			•	•		•	Adopted Fed+
Maine	Local	•	•	Some local	•			•	•		•	State
Maryland	State and Local	•	•		•		R	•	•		•	Adopted Fed+
Massachusetts	Local	•	•	Some local	•			•	•		•	State
Michigan	Local		•	Some local	•			•	•		•	Adopted Fed+
Minnesota	Local		•	Some local	•		R	•	•		•	Adopted Fed+
Mississippi	Local	•	•	Some local	•			•	•		•	Adopted Fed+
Missouri	Local		•	Some local	•		R,O	•	•		•	Adopted Fed+
Montanta	Local	•	•	Some local	•			•	•		•	Adopted Fed+
Nebraska	Local	•	•	Some local	•		R	•	•		•	Adopted Fed+
Nevada	Local	•	•	Some local	•		R	•	•		•	Adopted Fed+
New Hampshire	Local	•	•	Some local	•			•	•	•	•	State
New Jersey	Local	•	•	Some local	•			•	•		•	Adopted Fed+
New Mexico	Local	•	•		•		R	•	•		•	State
New York	Local		•	Some local	•		R	•	•		•	State
North Carolina	Local	•	•	Some local	•		R	•	•		•	Adopted Fed+
North Dakota	Local		•	Some local	•			•			•	State
Ohio	Local	•	•	Some local	•		R	•	•		•	Adopted Fed+
Oklahoma	Local		•	Some local	•		R,O	•	•		•	Adopted Fed+
Oregon	Local	•	•	Some local	•		R	•	•		•	Adopted Fed+
Pennsylvania	Local	•	•	Some local	•		R,O	•	•		•	State
Rhode Island	Local	•	•	Some local	•		R	•	•		•	State
South Carolina	Local	•	•	Some local	•			•	•		•	Adopted Fed+
South Dakota	Local	•	•	Some local	•		R	•	•		•	Adopted Fed+
Tennessee	Local	•	•	Some local	•			•	•		•	Adopted Fed+
Texas	Local		•	Some local	•		R,O	•	•		•	Adopted Fed+
Utah	Local	•	•	Some local	•			•	•		•	State
Vermont	Local		•	Some local	•			•	•		•	Adopted Fed+
Virginia	Local		•	Some local	•			•	•		•	Adopted Fed+
Washington	Local	•	•	Some local	•			•	•		•	Adopted Fed+
West Virginia	Local		•	Some local	•			•	•		•	Adopted Fed+
Wisconsin	Local	•	•	Some local	•			•	•		•	Adopted Fed+
Wyoming	Local		•	Some local	•			•	•		•	State

Appendix G – Life Cycle Analysis Supplemental Information

Several life cycle analyses have been published since the publication of DOE's 2006 study on the environmental and energy impacts of used oil re-refining and combustion. Eight studies along with their scope and description are listed and described below in Tables G-1 and G-2.

Table G-1. Description of Common Impact Categories [227]

Impact Category	Description
Resource Depletion	The total energy required and may include all upstream impacts. Depending on the impact method, this category can include the use and depletion of fossil fuels, minerals, and water.
Global Warming Potential	"Climate change is defined … as the impact of human emissions on the radiative forcing (i.e., heat radiation absorption) of the atmosphere. This may in turn have adverse impacts on ecosystem health, human health, and material welfare. Most of these emissions enhance radiative forcing, causing the temperature at the earth's surface to rise." [228]
Acidification	"Acidifying pollutants have a wide variety of impacts on soil, groundwater, surface waters, biological organisms, ecosystems and materials (buildings) … The major acidifying pollutants are SO_2, NO_X, and NH_X." [229]
Eutrophication	"Eutrophication covers all potential impacts of excessively high environmental levels of macronutrients, the most important of which are nitrogen (N) and phosphorus (P) … In aquatic ecosystems increased biomass production may lead to … depressed oxygen levels, because of the additional consumption of oxygen in biomass decomposition (measured as BOD or biological oxygen demand)." [230]
Human Toxicity	"The characterization factor of human toxicity … accounts for the environmental persistence (fate) and accumulation in the human food chain (exposure), and toxicity (effect) of a chemical. Fate and exposure factors can be calculated by means of 'evaluative' multimedia fate and exposure models, while effect factors can be derived from toxicity data on human beings and laboratory animals." [231]

[227] J. Bare, "Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) User's Guide," 2012.
[228] J. Guinée et al., Handbook on life cycle assessment. Operational guide to the ISO standards. I: LCA in perspective. IIa: Guide. IIb: Operational annex. III: Scientific background. Dordrecht: Kluwer Academic Publishers, 2002.
[229] *Ibid.*
[230] *Ibid.*
[231] M. Goedkoop, R. Heijungs, M. Huijbregts, A. De Schryver, J. Struijs, and R. van Zelm, "ReCiPe 2008: A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level - First edition (revised)," 2013.

Impact Category	Description
Ecotoxicity	"This impact category covers the impacts of toxic substances on aquatic, terrestrial, and sediment ecosystems." [232]

Among the 8 studies listed in Table G-2 below, 5 focus on the used oil industry outside of the United States. Two studies focus on California and one on the contiguous United States. The U.S. based studies and the IFEU study examine re-refining technologies that are reflective of current U.S. re-refining industry trends. A key methodological divide between the LCAs is whether they compare the impacts of different alternatives or whether they compare the differences in impacts between alternatives and a baseline. In the former case, studies are referred to as "total," because they compare the total magnitude of scenarios. For example, total studies compare the energy impact of re-refining of used oil against the energy impact of combustion. In the latter case, studies are referred to as "displacement," because they consider the fuels and resources displaced when switching from a baseline to an alternative. For example, displacement studies might compare the energy impacts of re-refining to combustion by first estimating the difference of re-refining used oil and refining from crude oil. Then they estimate the difference of combusting used oil and combusting petroleum and finally compare the two differences to generate a conclusion. Displacement studies can report negative results because the baseline can have a larger impact than the alternatives.

Table G-2. List of Life Cycle Analyses on Used Oil Combustion and/or Re-Refining Published since 2006

Author (Organization)	Year Location	Impact Criteria	Functional Unit	Synopsis
Abdalla and Fehrenbach [233] (IFEU)	2018 Germany	Acidification, carcinogenic risk, eutrophication, fine particulates, global warming potential (GWP), resource depletion	1 metric ton of used oil	Re-refining is generally better than combustion of used oils; combustion pathway is not reflective of U.S. technologies.
Botas et al. [234]	2017 Spain	Acidification, cumulative energy demand, GWP, human toxicity	1 metric ton of re-refined used oil	Re-refining used oil is better than refining crude oil in all metrics and scenarios.

[232] J. Guinée et al., Handbook on life cycle assessment. Operational guide to the ISO standards. I: LCA in perspective. IIa: Guide. IIb: Operational annex. III: Scientific background. Dordrecht: Kluwer Academic Publishers, 2002.
[233] N. Abdalla and H. Fehrenbach, "LCA for regeneration of waste oil to base oil," 2018.
[234] J. A. Botas, J. Moreno, J. J. Espada, D. P. Serrano, and J. Dufour, "Recycling of used lubricating oil: Evaluation of environmental and energy performance by LCA," *Resour. Conserv. Recycl.*, vol. 125, no. July, pp. 315–323, 2017.

Author (Organization)	Year Location	Impact Criteria	Functional Unit	Synopsis
Collins et al. [235] (American Petroleum Institute)	2017 California	Abiotic depletion, acidification, ecotoxicity, eutrophication, fossil fuel depletion, GWP, human health, human toxicity (carcinogenic and non-carcinogenic), ozone depletion	All oil flows in California in 2010 (435,000 metric tons)	Combustion of used oils is comparable to re-refining, especially if pollution controls are installed on combustion sources.
Geyer et al. [236] (CalRecycle)	2013 California	Acidification, ecotoxicity, eutrophication, GWP, human health cancer and non-cancer potential, human health criteria air pollutant	All oil flows in California in 2010 (435,000 metric tons)	Increasing used oil collections is good. Waste management strategies have impact tradeoffs.
Grice et al. [237] (Safety-Kleen)	2014 U.S.	GWP	1 gallon of re-refined used oil	Re-refined used oil shows lower GWP impacts than producing virgin oil from crude in all analyses.
Hassanain [238]	2017 Egypt	Acidification / eutrophication, carcinogens, climate change, ecotoxicity, fossil fuels depletion, land use, minerals, ozone layer, radiation, respiratory inorganics	1 metric ton of used oil	Re-refining is more environmentally friendly than combustion of used oils.
Kanokkanta-pong et al. [239]	2009 Thailand	Acidification, eutrophication, GWP, heavy metals	1 kg used oil	Results are mixed; processes examined are not reflective of current U.S. technologies

[235] M. Collins, K. Schiebel, and P. Dyke, "Life Cycle Assessment of Used Oil Management," 2017
[236] R. Geyer, B. Kuczenski, A. Henderson, and T. Zink, "Life Cycle Assessment of Used Oil Management in California Pursuant to Senate Bill 546 (Lowenthal)," 2013.
[237] L. N. Grice, C. E. Nobel, L. Longshore, R. Huntley, and A. L. DeVierno, "Life cycle carbon footprint of re-refined versus base oil that is not re-refined," *ACS Sustain. Chem. Eng.*, vol. 2, no. 2, pp. 158–164, 2014.
[238] E. M. Hassanain, D. M. M. Yacout, M. A. Metwally, and M. S. Hassouna, "Life cycle assessment of waste strategies for used lubricating oil," *Int. J. Life Cycle Assess.*, vol. 22, no. 8, pp. 1232–1240, 2017.
[239] V. Kanokkantapong, W. Kiatkittipong, B. Panyapinyopol, P. Wongsuchoto, and P. Pavasant, "Used lubricating oil management options based on life cycle thinking," *Resour. Conserv. Recycl.*, vol. 53, no. 5, pp. 294–299, 2009.

Author (Organization)	Year Location	Impact Criteria	Functional Unit	Synopsis
Pires and Martinho [240]	2013 Portugal	Abiotic depletion, acidification, eutrophication, GWP, freshwater aquatic and sedimental ecotoxicity, photochemical oxidation	All used oil in Portugal in 2010	Results are mixed; processes examined are not reflective of current U.S. technologies

[240] A. Pires and G. Martinho, "Life cycle assessment of a waste lubricant oil management system," *Int. J. Life Cycle Assess.*, vol. 18, no. 1, pp. 102–112, 2013.

Appendix H – Used Oil Industry Stakeholder Interactions

Prior to and during the course of undertaking the DOE effort to update the 2006 study, several used oil industry stakeholders expressed their interest and willingness to assist in developing the 2019 study. The DOE study team conducted several meetings with a number of those stakeholders, including the public meeting on October 16, 2019. At this meeting, which was announced in the Federal Register, there were 73 participants, 40 of which joined via WebEx. The meeting agenda included presentations by the DOE study team and industry stakeholders on the current status of the used oil industry, their perspectives, and recommendations on Federal strategies for used oil management, as well as a Questions-and-Answers session to discuss used oil industry issues and topics raised during the meeting.

The DOE study team members also visited the Vertex Used Oil Refinery in Columbus, Ohio, on September 13, 2019. Vertex is one of the largest U.S. processors of used motor oil and has a processing capacity of over 115 MMG annually, with operations located in Houston and Port Arthur, Texas; Marrero, Louisiana; and Columbus, Ohio. Vertex is a key supplier of Group II+ and Group III base stocks to the lubricants manufacturing industry in North America. The Columbus refinery has the capability and capacity to convert 1,500 barrels per day of used motor oil into vacuum gas oil. Vertex uses a two-step process to separate useful VGO from the waste products in spent passenger car used motor oil. The Vertex refinery and the DOE team visiting the facility are shown in the picture below.

From left to right:

Kyle Snider (Vertex), Benjamin Cowart (Vertex), Tim Reinhardt (DOE/FE), Evan Frye (DOE/FE), Mauri Lappinen (Lappinen Energy Consulting), Ryan Peay (DOE/FE), Shawn Bennett (DOE/FE)

The public meeting agenda and used oil industry stakeholder participants of the public meeting are provided below:

Beneficial Reuse Options for Used Lubricating Oil
October 16, 2019
1:00 – 5:00 PM EST
U.S. Department of Energy
1000 Independence Avenue, SW, Washington, DC 20585
Room 4A-104
Agenda

1:00 – 1:10 pm	Welcome and acknowledgements, background, meeting objectives (Ryan Peay, DOE)
1:10 – 1:20 pm	Overview of the Oil and Natural Gas Office program (Tim Reinhardt, DOE)
1:20 – 1:30 pm	Energy landscape (Evan Frye, DOE)
1:30 – 2:00 pm	Initial findings and observations for selected 2019 study topic areas
2:00 – 3:00 pm	Three stakeholder presentations (20 minutes each)

- Used Oil Sources and Uses – An Overview of the U.S. Market (Ian Moncrieff, Kline)
- Increasing the Beneficial Reuse of Used Lubricating Oil (Scott Parker, NORA)
- Maryland Used Oil Collection Program (Melissa Fliaggi, Maryland Environmental Services)

3:00 – 3:20 pm	Break
3:20 – 4:00 pm	Two stakeholder presentations (20 minutes each)

- API Perspectives and Recommendations on Federal Strategies for Used Oil Management (David Lax, API; Charlie Rau, ExxonMobil; Terry Thiele, TVThiele LTD)
- UORC Perspectives and Recommendations on Federal Strategies for Used Oil Management (Leigh Harrington, Safety-Kleen)

4:00 – 4:10 pm	EPA Perspectives (Jeffrey Gaines)
4:10 – 4:50 pm	Topical Q&As and Recommendations
4:50 – 5:00 pm	Wrap Up and Next Steps

Beneficial Reuse Options for Used Lubricating Oil Meeting

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Acknowledgements

During the course of updating the 2006 study, the DOE team has interacted and conducted meetings with a diverse group of used oil industry stakeholders. They were eager to assist DOE and have provided valuable information and inputs and answered questions raised by DOE. The materials received from the stakeholders contain information, reference data, insight, and recommendations that are beneficial to those interested in learning more about the used oil industry, dynamics, status, issues, and its future. The DOE thanks the various stakeholders for their participation and inputs.

Attachment 1 – Federal Strategy on Used Oil Management and Beneficial Reuse Options to Address Section 1. Energy Savings from Lubricating Oil, Public Law 115-345

U.S. DEPARTMENT OF ENERGY

Office of Oil and Natural Gas
Office of Fossil Energy

FEDERAL STRATEGY ON USED OIL MANAGEMENT AND BENEFICIAL REUSE OPTIONS TO ADDRESS SECTION 1. ENERGY SAVINGS FROM LUBRICATING OIL, PUBLIC LAW 115-345

DECEMBER 2020

Federal Strategy on Used Oil Management and Beneficial Reuse Options to Address Section 1. Energy Savings from Lubricating Oil, Public Law 115-345

U.S. Department of Energy
Office of Fossil Energy

December 2020

Executive Summary

On December 21, 2018, Congress approved Public Law (P.L.) 115-345 directing the Secretary of Energy, in cooperation with the U.S. Environmental Protection Agency (EPA) and the Director of the Office of Management and Budget (OMB), to review and update a report on the energy and environmental benefits of the re-refining of used lubricating oil that had been prepared pursuant to Section 1838 of the Energy Policy Act of 2005. That report, titled "Used Oil Re-refining Study to Address Energy Policy Act of 2005, Section 1838," dated July 2006, was "a study of the energy and environmental benefits of the re-refining of used lubricating oil … including recommendations of specific steps that can be taken to improve collections of used lubricating oil and increase re-refining and other beneficial re-use of such oil."

P.L. 115-345 directed the U.S. Department of Energy (DOE) to consult with relevant Federal, State and local agencies and affected industry and stakeholder groups, update data that was used in preparing the 2006 report, and prepare and submit to Congress a coordinated Federal strategy to increase the beneficial reuse of used lubricating oil, that is consistent with national policy as established pursuant to Section 2 of the Used Oil Recycling Act of 1980 (P.L. 96-463).
DOE met on multiple occasions with representatives of key stakeholder groups within the used oil sector to gather input on the status of the industry, held a public meeting on October 16, 2019 at DOE offices in Washington, D.C. to engage a wider variety of stakeholders and gather additional input. That meeting included 73 individuals from more than 50 organizations and companies in attendance in-person or via WebEx. The information gathered, together with findings from independent research conducted by DOE staff, were used to update the 2006 report. The 2019 report was reviewed by OMB and EPA prior to submission to Congress, as specified in P.L. 115-345.

P.L. 115-345 stipulates that the coordinated Federal strategy must address measures needed to (a) increase the responsible collection of used oil, (b) disseminate public information concerning sustainable reuse options for used oil, and (c) promote sustainable reuse of used oil by Federal agencies, recipients of Federal grant funds, entities contracting with the Federal Government, and the general public.

This document includes a number of recommendations for action on the part of DOE, independently and in coordination with other Government agencies and entities, to improve collections of used lubricating oil and increase re-refining and other beneficial re-use of such oil.

Table of Contents

I. Legislative Language

This report responds to legislative language set forth in Public Law (P.L.) 115-345 to direct the Secretary of Energy to review and update a report on the energy and environmental benefits of the re-refining of used lubricating oil, where in it is stated:

SECTION 1. ENERGY SAVINGS FROM LUBRICATING OIL
Not later than 1 year after the date of enactment of this Act, the Secretary of Energy, in cooperation with the Administrator of the Environmental Protection Agency and the Director of the Office of Management and Budget, shall—

(1) review and update the report prepared pursuant to Section 1838 of the Energy Policy Act of 2005;

(2) (2) after consultation with relevant Federal, State, and local agencies and affected industry and stakeholder groups, update data that was used in preparing that report; and

(3) (3) prepare and submit to Congress a coordinated Federal strategy to increase the beneficial reuse of used lubricating oil, that—

(A) is consistent with national policy as established pursuant to Section 2 of the Used Oil Recycling Act of 1980 (Public Law 96–463); and

(B) addresses measures needed to—

(i) increase the responsible collection of used oil;

(ii) disseminate public information concerning sustainable reuse options for used oil; and

(iii) promote sustainable reuse of used oil by Federal agencies, recipients of Federal grant funds, entities contracting with the Federal Government, and the general public.

Approved December 21, 2018.

II. Implementation Plan

Upon receipt of the updated report and this strategy, and depending on further guidance from Congress, DOE would have a coordinating role, as appropriate, in implementing these recommended actions with relevant Federal agencies. Further action will require that Congress provide direction and resources enabling Federal agencies to engage and work together on implementing these recommended actions through the following steps:

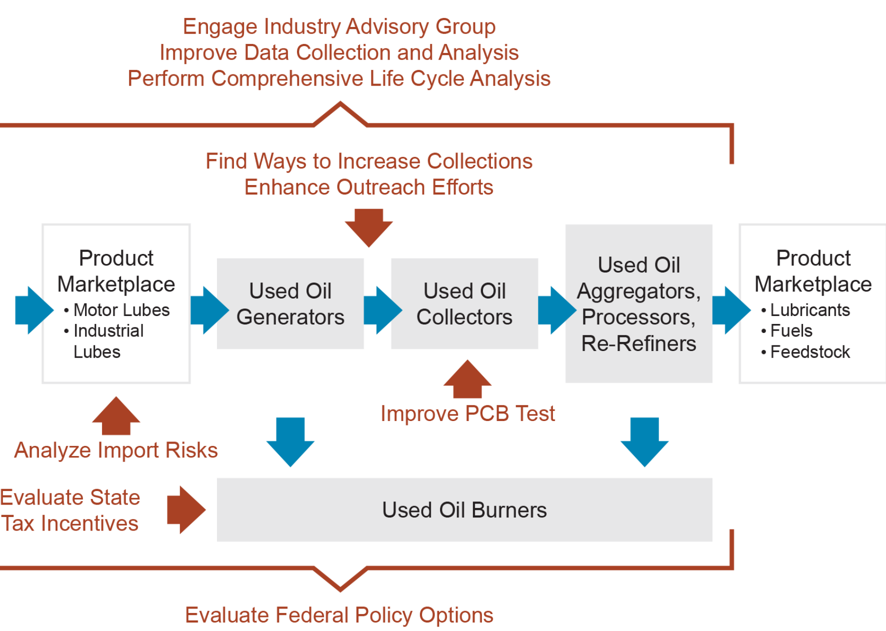
Step 1 – The designated lead agency assigns a project manager and associated staff, responsible for the implementation of this strategy with clearly defined responsibilities and reporting obligations.

Step 2 – The assigned project manager coordinates activity in each of the action areas according to the implementation steps outlined below and reports regularly on the progress to management.

Step 3 – The lead agency reports on the progress made towards full implementation of the recommended actions to the stakeholder groups involved in the used oil industry through timely meetings that allow for feedback to agency management from participants.

The implementation steps for each of the recommendations listed in the updated 2019 Report are provided below. Figure 1 shows the application of the recommendations relative to the used industry oil stakeholder categories described in the report.

Figure 1. Application of Recommended Actions across Stakeholder Categories



III. Information Exchange and Outreach Recommendations

- Establish a Stakeholder Advisory Group to gather and evaluate additional information related to used oil collection and re-use, to address unresolved issues identified in this updated report and beyond, and to develop strategies to promote the beneficial utilization of used oil. This group should include members of all stakeholder groups, whether directly or through industry association, including refiners, re-refiners, processors, generators, collectors, burners, State regulators, and non-profits associated with waste management and recycling. The Stakeholder Advisory Group should meet at a frequency determined to be most effective for the generation of useful advice and timely review of analytical products produced under other recommended actions outlined in this report.
    a. Initiate internal approval process for creation of a Stakeholder Advisory Group; obtain approval and funding.
    b. Identify potential participants, obtain approvals, engage candidates, and finalize membership.
    c. Identify key objectives and formal charge for group, establish proposed frequency of meetings, and obtain approvals.
    d. Set up inaugural meeting date.

    Estimated Timing: 4 to 6 months to first meeting, pending candidate response and agency approval.

- Work with relevant agencies to review and, where appropriate, refresh and enhance webpages related to used oil recycling and regulations. For example, collect data and information to update EPA's public website information related to used oil management (i.e., *Managing Used Oil: Answers to Frequent Questions for Businesses*).
    - Coordinate with agency representatives to carry out a review of used oil information on agency websites (e.g., DOE and EPA).
    - Prepare new content, as needed, based on 2019 Updated Report and other subject matter expert inputs.
    - Revise website content through established website revision channels.

    Estimated Duration: 4 months.

- Investigate ways to inform do-it-yourself (DIY) oil changers of the locations of used motor oil recycling locations via a centralized website.
    e. Evaluate existing websites that act as clearinghouses for connecting DIY oil changers with used oil recycling locations and consider opportunities for sharing information and strengthening these websites' utility for encouraging wider used motor oil recycling activity.
    f. Develop alternatives for Federal participation and select best options in line with objectives.

g. Obtain approvals for collaboration and implement.

Estimated Duration: 3-4 months, depending on level of cooperation and contract vehicle.

- Based on the flexible "best practices" data collected from State surveys (see section below), investigate ways that Federal action might be used to increase used oil collections in lower population density areas (rural and farming communities) where recycling options are less convenient, and identify ways to improve public awareness and education programs that communicate the benefits of recycling used oils, particularly to specific subsets of DIYs.
    h. Following receipt of information developed in Section IV below, identify the top three demographics nationwide and the top three regions where enhanced public awareness has the greatest possibility for increasing used oil collections from DIYs.
    i. Work with national groups (including used oil industry groups [e.g., NORA), UORC, and others] and State and/or local jurisdictions to develop pilot, targeted public awareness campaigns to reach these selected demographic groups and these selected areas.
    j. Develop metrics for measuring the impacts of these pilot programs.
    k. Implement pilots and measure impacts, proceed if impacts justify investments.
    l. Develop additional phased rollouts of other outreach campaigns.
    m. Measure impacts and assess overall success; determine if ongoing efforts are merited.

    Estimated Duration: Phase 1 pilots completed 12-24 months after analysis of data from State surveys; Phase 2 completion of up to six outreach campaigns 24 months after completion of Phase 1 pilots.

IV. Data Collection and Research Recommendations

- Carry out research and data collection activities to better quantify estimates of: (1) oil losses in use, (2) volumes of used oil generated and collected, (3) volume of used oil burned or recycled onsite or lost to the environment, (4) volume of used oil burned as used oil, and (5) volumes of used oil processed to recycled fuel oil (RFO) and blended into HSFO or exported as used oil.
    a. Develop data sources and analytical protocols for estimating each of the key used oil data sets identified above.
    b. Identify data gaps and missing analytical tools.
    c. Develop options for filling these gaps and acquiring these tools to include data purchases, industry surveys (in coordination with Stakeholder Advisory Group), and potentially requests for information (RFI).
    d. Work with industry groups, academic researchers, DOE's Energy Information Administration, National Laboratories, and others to complete baseline data

acquisition and build methodologies for timely updating of final data sets so that data trends can be characterized going forward.

e. Publish baseline data sets for peer review and comment.

f. Revise as needed and maintain public data sets online for public access.

Estimated Duration: 12-16 months.

- Using National Laboratory resources, carry out a scoping study to investigate the potential benefit of a National Lab research effort to develop an inexpensive disposable, quick test kit for testing used oil for the presence of PCBs.

g. Engage most appropriate national laboratory to carry out the study.

h. Carry out literature search and evaluate technology options for portable, quick PCB test methods, accessing input from members of the Stakeholder Advisory Group.

i. Identify barriers to commercial testing technologies and potential technology gaps inhibiting development.

j. Develop research needs and research plans for addressing technology gaps.

k. Perform preliminary market assessment to determine potential benefits of research program success.

l. Prepare final report.

Estimated Duration: 8-12 months.

- Work with State regulators to collect and compile State level data on used oil collection and disposition. Survey State regulators and develop a comprehensive set of "best practices" that provide insights on how to encourage used oil collection through State policies. Publish and promote the dissemination of this document.

m. Establish contacts with all active State used oil collection programs and gather information on how these State programs are operated.

n. Collect data to support metrics on the degree of success individual States have witnessed in engaging DIY residents to participate in used oil collection.

o. Identify those State program practices that have the best track record.

p. Publish these findings to all State program managers.

Estimated Duration: 3-6 months.

- Collect information on and evaluate foreign used oil collection programs and identify "best practices" and insights for U.S. policies.

q. Establish contacts with foreign government used oil collection program representatives and gather information on how these programs are operated.

r. Collect data to support metrics on the degree of success foreign programs have witnessed in engaging residents to participate in used oil collection.

s. Identify those program practices that have the best record of success and which of those practices have the most applicability in the U.S.

t. Prepare a report on these findings with recommendations relevant to enhancing used oil collection and recycling in the U.S.

Estimated Duration: 8-12 months.

V. Data Analysis Recommendations

- Utilizing National Laboratory resources, carry out a comprehensive life cycle analysis that quantifies the relative energy and environmental costs of re-refining used oil to produce lubricants, burning used oil, and re-refining or processing used oil to non-lubricant products.
  a. Engage most appropriate national laboratory to carry out the study.
  b. Refine the literature search carried out for the 2019 report and engage past LCA authors as necessary to completely understand the boundaries and assumptions used in their studies.
  c. In coordination with Subject Matter Experts (SME) through the Stakeholder Advisory Group, design an LCA that will answer key outstanding questions regarding the various dispositions of used oil within the U.S. used oil industry.
  d. Carry out the study and a qualified peer review of the results; revise as needed.
  e. Publish the results.

  Estimated Duration: 12-16 months.

- Using data collected (see Section IV) carry out analyses of used oil recycling programs and current used oil dispositions to determine where efforts to increase collections should be focused.
  f. Utilizing data collected under actions in Section IV, carry out a comprehensive study of State and Federal regulations regarding used oil collection, the programs currently underway at the State and local level around the country, industry practices and challenges surrounding used oil collection, and expected future trends likely to impact used oil recycling economics and both DIFM and DIY behavior.
  g. Identify new opportunities for regulatory streamlining, targeted Federal investments and collaborative efforts between public and private sectors that can enhance used oil collection totals.

  Estimated Duration: 6 months after data gathering tasks are completed.

- Work with State agencies in selected States that offer State tax incentives to small businesses that buy space heaters to confirm whether the current results of those programs are aligned with State objectives.
  h. Work with State agencies in those States where such tax incentives are offered to obtain data that quantifies the amount of State taxes lost to this incentive,

the business nature of the enterprises utilizing the tax credit, the value of the credit to those enterprises and the potential impact of its loss.

i. Publish the findings.

Estimated Duration: 3-6 months.

- Work with the Department of Commerce and other relevant agencies to evaluate the economic and security risk of a sudden cut off in Group III lubricant imports and the likely responses of both the crude oil refining and the used oil re-refining industries to such an event.

j. Working with appropriate agencies, characterize the history and current status of U.S. lubricant imports.

k. Work with members of the Stakeholder Advisory Group and external SMEs to fully characterize the U.S. crude oil refining and used oil re-refining industries' ability to ramp up production of Group III/III+ lubricants, including the timing and costs of such action.

l. Working with relevant agencies, characterize the current sources of U.S. lubricant imports and the likelihood of import reductions under a range of future scenarios.

m. Assess under what situations or scenarios Group III lubricant imports might be curtailed (e.g., as a result of global events, including curtailments of Group III base stock production due to operational problems, such as manufacturing plant mishaps or geo-political developments involving the producing countries.)

n. Characterize the impact of an extended drop in supply of Group III/III+ imports and the potential range of impacts to U.S. economy and national security.

o. Recommend actions to reduce those risks, as appropriate.

p. Publish the findings.

Estimated Duration: 6-9 months.

VI. Policy Development Recommendations

- Consider the potential economic benefits of implementing a policy that would eliminate or reduce notices of violation and allow industry to manage used oil in "as-found" condition, including a more equitable approach to assigning liability for the introduction of PCB-contaminated used oils.
    a. Carry out internal review of past legislative proposals on this topic.
    b. Evaluate options for regulatory modifications to address the issues identified; outline challenges for implementation and options for addressing those challenges.
    c. Carry forward a recommendation, if appropriate.

    Estimated Duration: 2 months.

- Review current government purchasing preferences for bio-based lubricants and lubricants re-refined from used oil to identify opportunities to disseminate information on the established preference regarding use of recycled oil and bio-based lubricants and increase awareness. Conduct analysis to evaluate whether the inclusion of bio-based lubricants in the used oil collection stream contaminates the feedstock or negatively impacts the re-refining process.
    d. Undertake a study of technical complications in the re-refining of used oils from lubricants containing notable levels of select bio-based or ester base stocks and their implications should be completed.
    e. In coordination with Stakeholder Advisory Group and both external and internal SMEs, evaluate and characterize the technical complications caused by inclusion of bio-based lubricants in the used oil pool and their implications for re-refining processes and economics.
    f. In coordination with national labs, carry out any necessary LCA analyses to determine the relative costs and benefits to consumers, industry and the environment of federal purchases of bio-based lubricants versus lubricants from re-refined used oil.
    g. In coordination with relevant agencies, determine the impact of purchasing preferences for bio-based lubricants on sales of those products and the impact of revising such preferences. Develop options for reconciling these competing preferences.
    h. Carry forward a recommendation to the Administration if appropriate.

    Estimated Duration: 2 months.

- Evaluate the costs and benefits of tax incentives that encourage the re-refining of used motor oil, such as:

i. After consulting with appropriate Federal agencies, design and implement a series of economic evaluations, to be carried out by a suitably qualified economic consulting firm (or firms) using appropriate models, that quantify the costs and benefits of Federal:
    i. Investment tax credits and/or production tax credits that encourage the collection and refining of used motor oil and other used lubricating/industrial oils,
    ii. Incentives that discourage the burning of used motor oil and other used lubricating/industrial oils,
    iii. Incentives for domestic production of Group III lubricants,
    iv. Income tax deductions for any payment for used oil collection made on the part of used oil generators for oil that is subsequently re-refined, and
    v. Direct and indirect market impacts of the above incentives.

Estimated Duration: 8-12 months.

- **Consider options for providing grant funding or other incentives.**
    j. Carry out internal review of options for providing grant funding or other incentives under programs such as the DOE's Clean Cities Program, or other similar programs, for use of oils refined from used motor oils.
    k. Carry forward a recommendation, if appropriate.

    Estimated Duration: 1 month.

- Consider Federal options for supporting enhanced voluntary compliance auditing for used oil processors and re-refiners.
    l. In coordination with relevant agencies as needed, evaluate current State and Federal practices for auditing regulatory compliance of used oil processors and re-refiners.
    m. Evaluate options for modifications to address any compliance issues identified.
    n. Carry forward a recommendation, if appropriate.

    Estimated Timing: 2-3 months.

VII. Conclusion

P.L. 115-345 directed DOE to consult with relevant Federal, State and local agencies and affected industry and stakeholder groups, update data that was used in preparing the 2006 report, and prepare and submit to Congress a coordinated Federal strategy to increase the beneficial reuse of used lubricating oil, that is consistent with national policy as established pursuant to Section 2 of the Used Oil Recycling Act of 1980 (P.L. 96-463).

This document provides a number of recommendations for action on the part of DOE, independently and in coordination with other Government agencies and entities, to improve collections of used lubricating oil and increase re-refining and other beneficial re-use of such oil. P.L. 115-345 stipulates that the coordinated Federal strategy must address measures needed to (a) increase the responsible collection of used oil, (b) disseminate public information concerning sustainable reuse options for used oil, and (c) promote sustainable reuse of used oil by Federal agencies, recipients of Federal grant funds, entities contracting with the Federal Government, and the general public.

The recommendations outlined above must be placed within a strategic framework for their implementation. The legislation directing this update of the 2006 report requires that DOE prepare and submit to Congress “a coordinated Federal strategy to increase the beneficial reuse of used lubricating oil” that:

- Is consistent with national policy (Used Oil Recycling Act of 1980 – P.L. 96–463),
- Addresses measures needed to increase the responsible collection of used oil and disseminate public information concerning sustainable reuse options for used oil, and
- Promotes sustainable reuse of used oil by Federal agencies, recipients of Federal grant funds, entities contracting with the Federal Government, and the general public.