

Lubricants Can't Be Green ... Can They?

By John Sander, Vice President of Technology, Lubrication Engineers, Inc.

Introduction

Today, many want to “go green” in various aspects of their lives. The question is what does this mean? It is typically meant to be a business or lifestyle choice to act in environmentally friendly ways. Is “green” a legitimate term or is it just marketing fluff meant to sell product, promote a company, or make us feel good? The answers to this question can vary from person to person, business to business, and even government to government. Common terms that have been used to define something as green include: renewable, recyclable, reusable, nontoxic or less toxic, energy conserving, and waste reducing.



The goal of this paper is to show that an unlikely industry – lubrication – can be very green through responsibly planned purchasing, storage, use and disposal; and to challenge the limited regulatory view of green lubricants that fails to consider longer lubricant and component life, and decreased energy use.

The lubricants industry is part of the much larger petroleum industry. In the aftermath of catastrophic accidents, such as the Deepwater Horizon explosion in the Gulf of Mexico and the grounding of the Exxon Valdez near Alaska, both of which resulted in high profile ecological damage caused by huge amounts of crude oil being spilled into the environment, petroleum has developed a reputation as being a dirty industry. Incidences such as these are evidence that some organizations in the exploration, production and transportation segments of the petroleum industry have contributed to that negative reputation and continue to have their challenges, but the entire petroleum industry should not be found guilty by association. In fact, this industry has made possible many of the products that are responsible for the quality of life enjoyed by increasing numbers of people around the world.

Green Definitions

The term “green” has various synonyms: environmentally friendly, environmentally acceptable, and sustainable, just to name a few. Most of the terms used over the years have involved how something we do (or use) affects the natural environment in which we live, including air, water, soil and the natural organisms that live in them. The goal of green initiatives is to conserve resources, produce less waste, and minimize pollution. Today many organizations are embracing “sustainability” as the best way to describe these initiatives.

The U.S. Environmental Protection Agency provides this explanation: “Sustainability is important to making sure that we have and will continue to have, the water, materials, and resources to protect human health and our environment” [1]. The United Nations hosted the *2005 World Summit*, during which it was noted that sustainability requires the reconciliation of environmental, social equity and economic demands, called the “three pillars” of sustainability as shown in **Fig. 1**. [3] This Venn diagram of sustainability indicates that the three pillars are not mutually exclusive and can be mutually reinforcing. Although this description of sustainability is not universally accepted, it has become by many organizations and governments.

The chemical industry was ahead of the game. The industry actually began to consider environmental issues along with economic issues prior to the U.N.'s *2005 World Summit*. Early in the summer of 1997, the Chemical Manufacturers Association, American Chemical Society, the U.S. EPA, and various other groups sponsored the first *Green Chemistry and Engineering Conference* in Washington, D.C.

Paul Anderson, president of ACS at that time, said that green chemistry “challenges us to look at the entire life cycle of chemical production to create new ways to more efficiently produce useful products with less waste – or preferably no waste.”

Per Paul Tebo, then vice president for safety, health and environment at DuPont, said that green chemistry will focus on the following:

- Reducing emissions and waste with goal of zero emissions
- Efficiency in use of materials, energy and water, including substantial use of recycled and reused materials and growing reliance on renewable resources
- Inherently safer processes, distribution and products
- Reducing total system impact through tools such as life-cycle assessment
- Creating significant customer and societal value per unit of resources extracted
- Creating significant shareholder value [2]

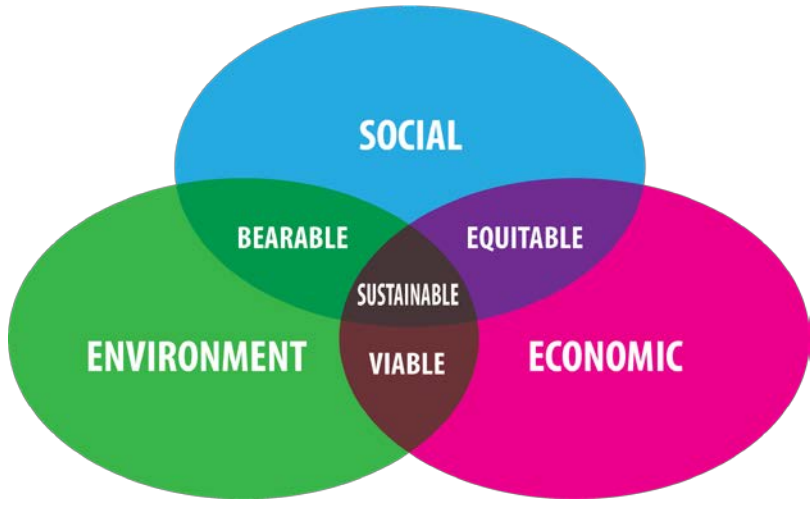
Contrary to popular belief, most lubricants – when properly used – could be considered environmentally considerate. Why? Lubricants reduce friction, which results in a reduction of energy consumption and increased equipment life. A properly formulated lubricant lasts longer, therefore generating less waste. The end users, original equipment manufacturers and government agencies still expect this performance, but are now also requesting low impact if the lubricant is released into the environment. During the vehicle design process, for example, lubricant formulations are being specified that will reduce engine emissions in vehicles with internal combustion engines.

Lubricants today can be formulated using high-performance biobased materials and meet the more traditional definitions of environmentally friendly, such as being biodegradable, low toxicity and non bioaccumulative. The remainder of this paper will point out various ways that lubricants can be green.

Lubricant Formulation

Traditionally, when a lubricant was formulated, it contained a mixture of two main ingredients: oil and additives. For grease, a third ingredient was added – a thickener. In modern times, formulation still follows this basic mixture, but within that the options have expanded dramatically, as many types of natural and synthetic base fluids can be used as the base of a lubricant, not just petroleum oil. Additives are included to

FIG. 1 | Venn Diagram of Sustainable Development: at the Confluence of Three Constituent Parts [3]



impart beneficial performance attributes, such as reduced friction (wear prevention), corrosion protection, heat removal (oxidation resistance), foam and air release, and water separation or emulsion, just to name a few. **Table 1** illustrates four key areas that formulators must consider when formulating products:

environmental,
performance, physical
and commercial.

The primary attribute desired by most end users from their lubricant is that it protects their asset from wear; therefore, increasing the asset's reliability and useful lifespan. For many regulators, the primary concern is that the lubricant be environmentally

friendly. For these agencies, lubricating properties are secondary, if considered at all. One of the first government regulations that directly affects lubricants is the U.S. EPA's 2013 *Vessel General Permit* amendment made to the *National Pollution Discharge and Emission System* rules of the *Clean Water Act*. The basis of this regulation is that all vessels greater than 79 feet long must use environmentally acceptable lubricants in all oil-to-sea interfaces, unless technically infeasible.

By the EPA's description, environmentally acceptable lubricants are biodegradable, minimally toxic and not bioaccumulative. The VGP went into effect Dec. 19, 2013. [4] This regulation provides no regulatory requirements for lubrication performance. It only regulates the three properties mentioned.

Yet, lubricants can be green in many ways that still consider performance, more in line with companies' aims in pursuit of sustainability. It's time to look at the more holistic view of green lubricants.

Holistic View of Green Lubricants

The traditional environmental lubricant has been one that has been either proven to be biodegradable or is formulated from biobased materials. Yet, from a more holistic standpoint, lubricants have been environmentally friendly in another way for years. If the proper product formulated for an application is chosen, it can improve equipment efficiency. As compared to the lubricants even 50 years ago, today's lubricants can be formulated to provide a much higher level of equipment protection and performance. If the sustainability model of green is considered, they can be more environmentally friendly, provide better performance, and improve the economic bottom line. Let's look at some ways lubricants can be green.

Renewable

Petroleum crude oil has long been thought of as a non-renewable natural resource. It is formed deep within the stratified rock that is part of the earth's crust. Crude oil is located and extracted from the rock and refined into many materials, including mineral lubricating oils. Technically, natural process could create more oil, but not within the lifetime of anybody currently living, thus for practical purposes it is a limited

TABLE 1 | Planning Consideration Areas

Environmental	Performance	Physical	Commercial
Ecotoxicity	Compatibility	State	Marketability
Biodegradability	Wear Reduction	Rheology	Packaging
Bioaccumulation	Oxidation	Tackiness	Storage
Renewable	Corrosion	Odor	Disposal
Recyclable	Water Separation	Volatility	Personnel
	Foaming	Color	Cost/Price

resource that will eventually run out. For many years, doomsayers have pronounced the impending end of petroleum crude oil. In 2014, BP estimated that we had 53 years' worth of oil left in the ground if we continued with current production and usage rates. [5]

Through improved exploration techniques, increased use of hydraulic fracturing, and enhanced recovery processes; this number has increased over the years, even though world population continues to grow. In addition, efforts have been made to produce oil from renewable vegetable, animal and algae sources – canola, soybeans and cattle, to name a few. These efforts represent a return to the lubricants used by humans long before petroleum crude was found and refined. These sources are considered renewable, because they come from live organisms. Petroleum oil took millions of years to form in the ground. Renewable products grow, are harvested, and are turned into products within a relatively short time.

Most oils taken directly from animal and vegetable sources, however, do not yield stable lubricants. It is this instability that makes them highly biodegradable, an environmental advantage. Much research has been conducted on renewable oils since the late 1980s; through genetic modifications and chemical processing, some of their insufficiencies are being overcome. Unfortunately, this usually results in base fluids that can be more expensive than mineral oils.



Canola Field in Denmark



Cattle Ranch in Montana

Biodegradable, Low Ecotoxicity, Non Bioaccumulative

Early environmentally acceptable lubricants were made from biobased materials or were biodegradable; most were formulated using vegetable oil based fluids. Concessions often had to be made by the users when putting these products into service. They typically would become jelly-like at low temperatures and oxidize rapidly at operating temperatures. They were also more expensive than their mineral oil counterparts. This meant that for a user to employ green lubricants they had to pay more for a product that didn't perform as well. There were not many laws in place forcing users to buy them, so only hardcore environmentalists used them.

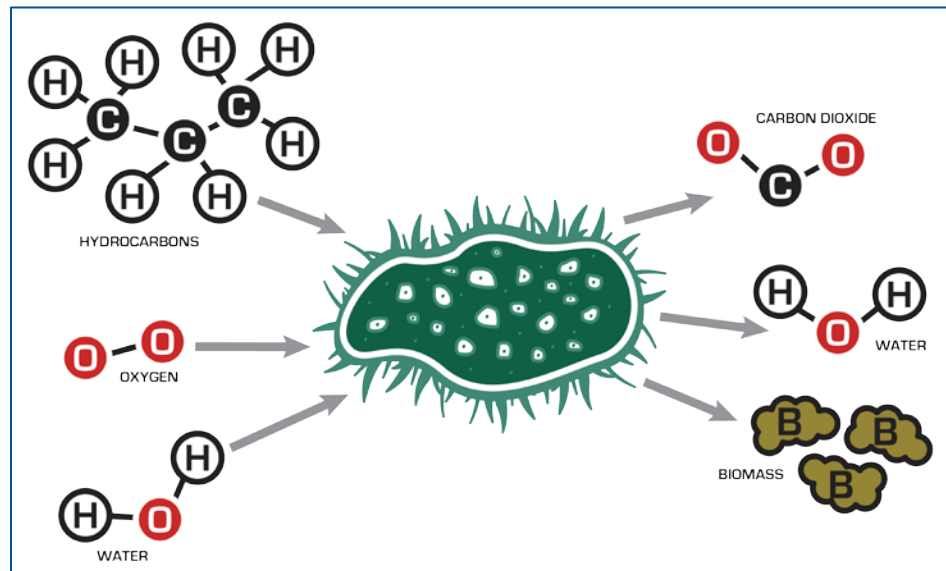
Governments are beginning to put more emphasis on EALs by enacting laws, such as the U.S. EPA VGP laws, making it more difficult for companies to avoid using them. Fortunately, many options are available today through genetically improved vegetable oils or high-performance synthetic fluids, so that higher performing products can be formulated to overcome the low- and high-temperature concerns of the early products. Along with biodegradability, toxicology has become part of the requirement for a lubricant to be green, meaning that formulators now must also consider ecotoxicity and bioaccumulation.

Government laws, such as the EPA VGP, set forth quantifiable requirements to show that a lubricant is an EAL. While the VGP is a self-certifying program, there are also marketing based approvals, such as the European Union’s Ecolabel, that include specific test requirements, product formula audits, and fees paid for registration and use of their approval logo. These approvals do not place any requirements on lubrication performance, however, just on biodegradability, toxicity and bioaccumulation. The typical tests for evaluating lubricants and lubricant ingredients for these three properties are listed in **Table 2** [6] [7], followed by a summary of the requirements for each.

TABLE 2 Common Consideration Standards for Lubricants		
Biodegradability	Toxicity	Bioaccumulation
ASTM D6006: Assessing Biodegradability of Hydraulic Fluids	ASTM D6081: Aquatic Toxicity Testing	OECD 107: Partition Coefficient, Shake Flask Method
ASTM D5864: Determining Aerobic Aquatic Biodegradation / OECD 301B: Freshwater Modified Sturm Test	OECD 201: Freshwater Alga and Cyanobacteria, Growth Inhibition Test	OECD 117: Partition Coefficient, HPLC Method
ASTM D6139: Determining Aerobic Aquatic Biodegradation, Gledhill Shake Flask / OECD 301D: Freshwater Closed Bottle Test	OECD 202: Daphnia sp., Acute Immobilization and Reproduction Test	
ASTM D6731: Determining Aerobic, Aquatic Biodegradability, Closed Respirometer / OECD 301E: Modified Biodegradation Test	OECD 203: Fish, Acute Toxicity Test	
ASTMD7373: Predicting Biodegradability, Biokinetic Model	OECD 210: Fish, Early-Life Stage Toxicity Test	
OECD 301C: Modified MITI Test	OECD 211: Daphnia Magna Reproduction Test	
Note: ASTM standards [10] and OECD Tests [11] used as references.		

Biodegradability

Biodegradability is a measure of the persistence, or breakdown rate, of a substance through biological action while in the natural environment. Most of the tests listed in **Table 2** evaluate biodegradability through the conversion of the lubricant from a hydrocarbon to a more basic molecule, carbon dioxide, through metabolism and respiration of microorganisms, such as bacteria.



Biodegradability

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Biodegradable products are identified as readily or inherently biodegradable. This is determined by the percentage with which they biodegrade to their natural state, when subjected to sunlight, water and microbial activity, in 28 days. Products are considered “readily biodegradable” if they biodegrade anywhere from 60-100 percent. “Inherently biodegradable” products are those that will biodegrade from 20-60 percent. [8]



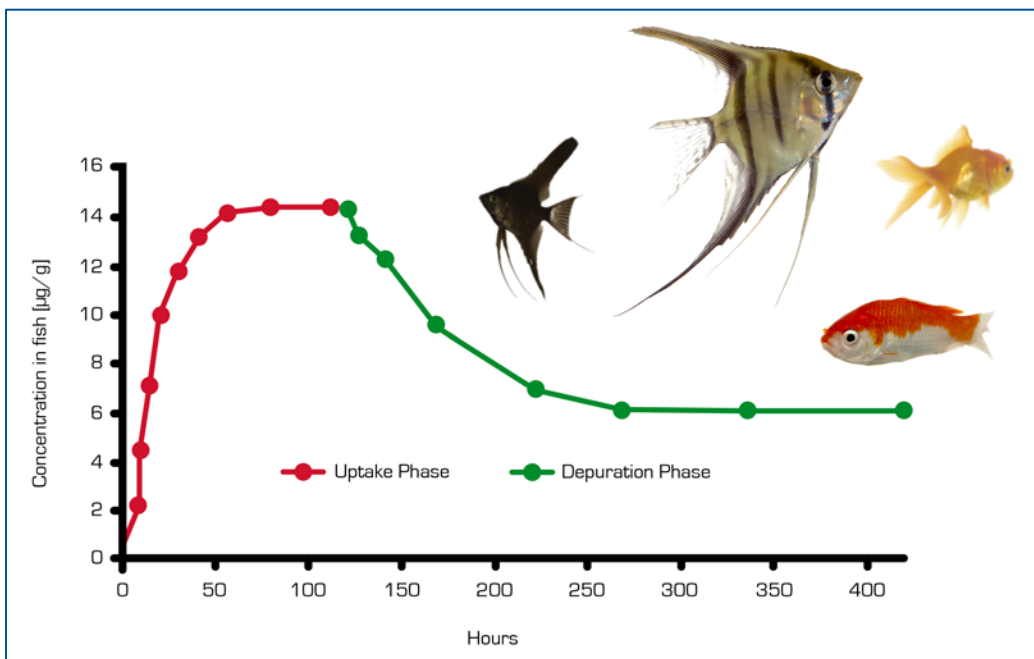
Daphnia (water flea), as used in OECD ecotoxicity testing.

Ecotoxicity

Ecotoxicity is a measure of the toxicity of a chemical substance to organisms in the environment. The tests listed in **Table 2** employ species that are used to provide indications of whether a chemical is either acutely or chronically toxic to the environment. Although this list contains almost exclusively marine organisms, there are also tests that use plants, bacteria and various other organisms. Frequently, the result will be presented as an EC (effective concentration) value or LC (lethal concentration) value.

Bioaccumulation

Bioaccumulation is a process through which chemicals are taken up by organisms either directly from exposure to a contaminated environment or by consumption of food containing the chemical. For bioaccumulative compounds, the principal route of movement into and through aquatic food webs appears to be dietary ingestion rather than bioconcentration from water because these compounds generally exhibit low water solubility and tend to concentrate in the lipid fractions of biological tissues. [6] Therefore, the tests evaluate the partition coefficient, or the tendency of a compound to separate from water. Typically, materials are evaluated for separation into octanol or water. The ones that prefer octanol could accumulate in the fat of organisms and bioaccumulate.

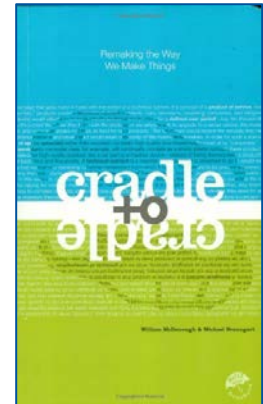


Bioaccumulation

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Cradle to Grave, Cradle to Cradle

When the environmental movement began, many people wanted to see producers of materials, such as lubricants, be responsible for them from “cradle to grave,” or from inception through use and disposal. In 2002, scientist Dr. Michael Braungart and architect William McDonough published their book **Cradle to Cradle: Remaking the Way We Make Things**, which called for a transformation of human industry through ecologically intelligent design. [9] They suggested that the things we use must be designed in an ecologically sustainable manner creating what could be considered a circular product life cycle. Two ways to accomplish this are reuse and recycling.



*Cradle to Cradle by
Braungart & McDonough*

For convenience, many things made today are disposable. They are used once or twice and then thrown away. This means that they end up in a disposal resting place, such as a landfill, or irresponsibly tossed aside as pollution. Most lubricants are liquid-based; they are sometimes poured out and seep into soil or water, which contaminates a natural resource that we need to live. Any effort to reuse or recycle lubricants is green.

Reuse

Some lubricant packaging, such as steel drums and bulk transfer tanks, can be emptied, sent back, refurbished and refilled with new lubricants or other chemicals. However, most lubricants cannot be reused because of degradation and contamination. Some end users have tried to reuse lubricants with limited success. For example, used lubricants are sometimes applied to moving chains. This is not considered a best lubrication practice but success varies depending upon condition of the used lubricant. Another reuse for lubricants is that they are collected and burned as heating fuel oil. The fuel is needed as an energy source, so this approach is more green than dumping into a landfill or pouring into the environment.

Recycling

An entire new segment of the lubricants industry exists called re-refiners. In the infancy of re-refining, waste oil collectors would take spent lubricant back to their facility, remove the water, filter out the solids, and resell it for various lubrication uses. Modern re-refiners collect the used lubricant, take it to their facility, remove water and solids, but then – unlike their predecessors – they introduce it into a refinery process just like crude oil. After processing, new high-quality base oils are produced that have been found to be of equal or better quality to virgin base oils. These can be used to produce new lubricants, starting the process over. This has been called a “closed loop” process. [10]

Resource Conserving

Yet another way things can be considered green is that they reduce the amount of natural resources that must be used to produce them. There are various ways this can be achieved when using lubricants. One of the main purposes of lubricants is to reduce friction, which minimizes equipment wear. Laws of physics can be used to show that two surfaces with a lower coefficient of friction run more efficiently and consume less power. Power consumption can be measured in several ways, including fuel economy, electrical consumption or productivity (units/hour or similar).

These efforts can be converted into monetary figures, meaning that they can create economic benefits in addition to the environmental benefits of using fewer resources. Occasionally, it can even be shown that the money saved is more than the amount that may have been spent on a more expensive lubricant or a lubricant that needed to be changed more frequently. [11]

Because of concerns with climate change, an important initiative pursued by many of the world's governments is to reduce greenhouse gas emissions. Power plants, businesses and individuals are inspired to reduce their carbon footprint. As an example of how this affects engine oils, the most recent diesel and gasoline engine emission regulations have included requirements for fuel economy improvements as a means of reducing carbon dioxide emissions. Aside from vehicle aerodynamics and engine upgrades, engine lubricants were also affected. OEMs have begun to require decreases in viscosity grade recommendations without sacrificing engine durability. Certain engine oil ingredient levels are regulated so that they do not negatively impact vehicle emission system equipment. Aside from reducing environmental impact, the lubricants are being required to protect the physical assets, making them last longer.

In addition to extending the life of the asset, the lubricant itself can be formulated to last longer. Proper selection of lubricant ingredients can result in products that are capable of extended drain performance. Most OEMs make lubrication drain interval recommendations that are based on the lifespan of the typical lubricant that would be used in the equipment. Through proper base fluid and additive selection, it is possible to formulate lubricant products that operate for extended periods of time under proper maintenance without needing to be changed. The result in this case is less lubricant purchased, less used lubricant disposed, less maintenance labor, and ultimately less financial resources spent. Less oil, as a natural resource, is consumed; therefore, extending drain intervals is a green activity. However, drain intervals should not be extended without normal filter changes and monitoring through oil analysis.

Improved Reliability

Ultimately, a successful green lubricant program is the responsibility of the end user. A world class lubrication reliability program improves equipment reliability and uptime with the fringe benefit of creating a holistic green lubricant program. It could be argued that the cornerstone of a successful green lubricant program is a lubricant-centered reliability program.

This includes training employees, as well as keeping lubricants clean and dry with filtration, desiccation and fill level monitoring. If an oil analysis program is also



included in the reliability program, drain intervals can be optimized so that good lubricant is not disposed of before necessary. Finally, when tools such as automatic lubrication systems are used, machines run more efficiently and use less energy.

Numerous case studies have shown that when lubrication reliability programs are implemented, companies reduce costs and improve their profitability, thus becoming more sustainable economically as well as environmentally.

Conclusion

It may be surprising, but lubricants can truly be green. While many people look at green lubricants just as biodegradable, low toxicity and non bioaccumulative, this paper has shown that lubricants can be considered green in other ways as well. The limited standard imposed by regulatory agencies does not fully consider how lubricants can be considered green. For example, the potential for a world class lubrication reliability program to lead to energy savings and extension of lubricant and component life ought to be considered as part of a holistic view of what it means to be green.

It is up to the end user to take advantage of as many of these green options as possible. The question then becomes: “Where do I start?” The recommendation of this author would be to start at the end. Almost none of the green lubricant options discussed in this paper are going to be as green as they can be without a world class lubrication reliability program. Implementing a lubrication reliability program is a daunting task; it is often described as a journey. To help with this journey, companies should choose a lubricant supplier that can be a partner – not just a supplier. In the end, a successful implementation will result in improved environmental, economic and social (personnel and customers) sustainability: the three pillars of sustainability.

The answer to the question, “Can lubricants be green?” is an unequivocal yes!

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