



U.S. DEPARTMENT OF
ENERGY

Office of
**ENERGY EFFICIENCY &
RENEWABLE ENERGY**

DOE Investments

in Environmentally Acceptable Lubricants for Hydropower Applications

Environmentally acceptable lubricants (EALs) are defined as lubricants that meet U.S. Environmental Protection Agency (EPA) standards for “biodegradability, toxicity, and bioaccumulation potential that minimize their likely adverse consequences in the aquatic environment, compared to conventional lubricants.”¹ Restrictions from state, local, and federal agencies, as well as a growing awareness of the environmental risks associated with petroleum-based lubricants, have shifted government and industry to seek out high-performing EALs. The U.S. Department of Energy (DOE) is working to reduce the environmental impacts of hydropower development and operation by investing in tools and methods to develop, demonstrate, and validate EAL materials.

Background

Hydropower equipment requires lubricants and hydraulic fluids to operate efficiently. Most hydropower equipment uses petroleum-based mineral oils, which are generally high-performing and inexpensive but have significantly damaging environmental impacts in the event of a spill or accidental release, or if they mix with water used for generation. These events result in expensive mitigation, litigation, and/or penalties from regulatory authorities. Using environmentally acceptable lubricants, or EALs, is one way to avoid these issues.

The most common types of EALs are:

- **Bio-based oils**, which are derived from natural sources with minimal modification. They are the most common type of base oil, often referred to as vegetable or plant oils.
- **Synthetic esters**, which are formulated via chemical synthesis of bio-based materials (e.g., animal fat and vegetable oil) to create materials with desirable properties for lubrication.
- **Polyalkylene glycols**, which are a type of synthetic lubricant. Although made from petroleum-based materials, polyalkylene glycols can be highly biodegradable and water soluble.

Challenges

While EALs represent a promising opportunity, certain challenges make it difficult to promote their adoption and wide-scale use. Fully developed and cost-effective EALs specifically designed for hydropower applications are still being researched. Further, newly formulated EAL products must compete with the established petroleum-based products, which are typically less expensive. Even though biodegradable base oils are commercially available, the additives required to produce cost and performance competitive EALs are not, making production more difficult and costly. Existing hydropower equipment is optimized for the use of mineral oil lubricants, and EAL oils must be compatible without performance issues. Finally, not all EALs meet the thermo-oxidative stability characteristics required for hydropower operations. DOE is working with industry to tackle these challenges and help make EALs market ready.

¹ https://www3.epa.gov/npdes/pubs/vgp_environmentally_acceptable_lubricants.pdf



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SBIR/STTR Funding Opportunity

To help mitigate industry risk of adopting EALs at their current state and to stimulate technological innovation, DOE included a topic focused on reducing costs and increasing performance of EALs for hydropower applications in the FY 2018 Small Business Innovation Research (SBIR), and Small Business Technology Transfer (STTR) funding opportunity. SBIR/STTR awards are typically awarded in two phases, with Phase II funding awarded after the evaluation of Phase I work. In this opportunity, awardees were required to carry out early concept feasibility, including lab testing on a limited number of EALs during Phase I, and the development of a suite of EALs for hydropower applications during Phase II. Based on the Phase I progress of work, DOE awarded the following three small businesses with Phase II grants in July 2019.²

POLNOX CORPORATION (LOWELL, MASSACHUSETTS)

Polnox Corporation is developing environmentally friendly hydraulic fluids and lubricant formulations for turbine and hydraulic systems in hydropower stations using two of the company's proprietary additives and additional treatments to improve performance. The company's main focus is on developing key eco-friendly additives to

improve performance properties, such as antioxidant corrosion inhibitors, demulsifiers, and anti-wear agents. They are also selecting suitable base stock oils that are thermally stable, biodegradable, and non-toxic. During Phase I, Polnox formulated and tested superior biodegradable EALs that appear to have met or exceeded the primary requirement specifications listed by the United States Army Corps of Engineers. During Phase II, Polnox is working on additional optimization, scaling, and testing to meet both primary and secondary attributes for hydropower applications.

TETRAMER TECHNOLOGIES LLC (PENDLETON, SOUTH CAROLINA)

Tetramer Technologies LLC is developing synthetic biodegradable hydropower turbine oil based on esterified propoxylated glycerol (EPG) that will provide cost and performance benefits when compared to other types of EALs. Tetramer's general approach is to synthesize a series of lubricants and evaluate their base physical properties, down-selecting promising candidates for in-depth property analysis for the targeted commercial application. In Phase I, Tetramer demonstrated EPG's technical potential as an EAL base oil, with pour point temperatures of $< -9^{\circ}\text{C}$, viscosity in the International Standards Organization viscosity grade range of 46–68, and adequate wear resistance. The team also demonstrated methods

of modifying EPG base oils using environmentally friendly components. During Phase II, Tetramer will optimize, refine, and validate EPG compositions through testing as fully formulated turbine oil EALs and will perform in-depth analysis into thermal properties, viscometrics, and rust and wear properties. Additionally, the company will investigate the oils for other applications such as transformer oils and greases.

RIKARBON, INC. (NEWARK, DELAWARE)

RiKarbon, Inc. is using its proprietary technology to produce and commercialize EALs (BioLubes) from natural oils and plant matters. RiKarbon will evaluate various properties and the biodegradability of BioLubes to qualify as EALs for hydropower and other applications. In addition, the company will conduct process design and techno-economic analysis. During Phase I, RiKarbon synthesized six different bio-based base oils of varying structures and properties; determined structural properties of BioLubes to evaluate which product is most suitable for hydropower turbines; and determined stability, key properties, bio-based carbon content, and biodegradability of BioLubes. The company also performed a techno-economic analysis. During Phase II, RiKarbon will formulate and test a commercial application of BioLubes that can be continuously produced per market requirements and satisfy regulatory requirements.

² <https://www.energy.gov/eere/articles/eere-helps-american-small-businesses-436-million-phase-ii-innovation-projects>