Fact Sheet

Defense Advanced Research Projects Agency

3701 North Fairfax Drive
Arlington, VA 22203-1714
www.darpa.mil/newsroom

May 2009

BIOFUELS FOR THE U.S. MILITARY

Overview

The Department of Defense requires a steady supply of military jet fuel ("JP-8") to meet the energy needs of our Armed Forces. Congress has instructed DoD to explore a wide range of energy alternatives to reduce the military's reliance on foreign oil imports.

- Agriculture and aquaculture offer promising opportunities to create "bio-fuels." There are a variety of agricultural and aquacultural crops that can be optimized and harvested to produce desirable fuel characteristics. However, current techniques and processes are inefficient and result in JP-8 that is prohibitively expensive.
- Therefore, DARPA is undertaking new research to enable the efficient and economical production of military-grade jet fuel (JP-8) from agricultural and aquacultural products that are oil rich yet not competitive with the food supply – as is the case with ethanol, for example.

DARPA's pursuit of alternative biofuels

DARPA often is called upon to accelerate technological development by assembling multidisciplinary teams of scientists and engineers to achieve remarkable and in some cases revolutionary breakthroughs. In the DARPA Grand Challenge, for example, DARPA brought together teams of inventors, researchers, computer scientists, and engineers to rapidly advance the state of the art of robotic vehicular technology.

To look at biofuel surrogates for JP-8, DARPA once again is convening a diverse group of performers to more rapidly advance new technologies. Despite a considerable amount of excellent research progress, current commercial processes are research-driven, not necessarily end-product-driven. Additionally these ongoing efforts so far yield a fuel that is unsuitable for military aviation applications, which require **higher energy density** and a wide operating temperature range.

Biofuels from Agricultural Feedstocks

DARPA began its pursuit of alternative biofuels in 2006. The objective of DARPA's original BioFuels program was to provide proof of concept for producing surrogate JP-8 fuels from agricultural feedstocks. In particular, DARPA was interested in flexible processes that could produce surrogate JP-8 fuels from a wide variety of biomass.

(more)

Researchers at UOP LLC, General Electric Global Research, and University of North Dakota Energy and the Environment Research Center developed several processes to convert various vegetable oils to JP-8. The processes can use a variety of natural (vegetable) oils and animal fats (greases) as feedstocks, both edible and inedible. Because of differences among feedstocks and regional differences in availability, feedstock flexibility was an important element of the research effort. Researchers demonstrated the flexibility of the process with a variety of feed oils – the new processes are adaptable for soy, palm, canola, and coconut oil, inedible oils such as jatropha and camelina, and a variety of algal oils.

Using laboratory and small-scale pilot plant facilities, the researchers synthesized gallon quantities of bio-dervied JP-8 that met or exceeded the required key first-level specifications for JP-8. DARPA continues to work with the Department of Defense and commercial entities (aircraft and jet engine manufacturers) to establish specifications and validate properties of bio-based JP-8.

An additional contractor, Swedish Biofuels AB, continues development of a JP-8 equivalent derived from grain crops. Their initial JP-8 sample also met or exceeded key first-level specifications for JP-8.

DARPA's New Effort - BioFuels: Cellulosic and Algal Feedstocks

DARPA's new BioFuels: Cellulosic and Algal Feedstocks program, also known as the BioFuels: Alternative Feedstocks program, will build on these successes and will demonstrate economic and scalable processes for producing JP-8 surrogate fuels from agricultural and aquacultural crops that will not compete with food supplies.

The Cellulosic and Algal Biofuels program will develop affordable alternatives to petroleum-derived JP-8 from **algae** and from **cellulosic biomass.** The program has a crucial financial caveat. Sufficiently energy-dense biofuel oil must be produced at a cost that is competitive with petroleum-derived fuels. DARPA seeks to produce a surrogate JP-8 that would cost *less than $3 per gallon at a production rate of 50 million gallons per year*.

- Cellulosic: The program will start by demonstrating 30% conversion energy efficiency (the conversion of biomass to actual fuel), by energy content, of feedstock material into JP-8. In the program's second phase, the contractor will demonstrate 50% conversion efficiency. Contractor: Logos Technologies.
- Algae: The program will initially demonstrate algae triglyceride production (a precursor to JP-8) at a projected production cost of $2 per gallon. In Phase 2, contractors will demonstrate production of algae triglyceride at $1 per gallon. Contractors will develop and demonstrate a process for affordable algae triglyceride production and conversion of the algae triglyceride into biofuel. By the end of phase I, contractors will deliver a 100-liter sample of algae-based biofuel for government testing. A larger sample (4,000 liters) will be delivered at the end of the program. Contractors: General Atomics and Science Applications International Corp.

The key to success

Key to the success for DARPA's new BioFuels initiative will be the identification of scalable processes that can economically convert cellulosic (non-food) biomass and algae to a surrogate military jet fuel (JP-8).

The production of biomass feedstock that can be converted to biofuels is, at its essence, a process of photosynthesis. Plants convert solar energy to stored sugars and oils that can be extracted and upgraded for use as various types of fuels Plants that store energy primarily as vegetable oil can produce significantly greater amounts of fuel per acre than sugar-based crops.

Technical challenges

Technical challenges include the following:

1. **Identifying oil rich algal crops** that can be grown and sustained in large quantities. Typically, algae is grown in and harvested from large pools (raceways) or in large tanks (photobioreactors). Each has their advantages and disadvantages. For example, bioreactors are more expensive to operate, however they allow for better environmental control and generally produce a higher energy density algal oil. Raceways are more readily expandable to large-scale operations and less expensive to operate, however they generally produce a lower energy density algal oil.

2. Identifying processes for the **economic extraction of triglyceride oils from algae**. Existing processes for the extraction of oils from algal crops are cost prohibitive and cumbersome to implement. To meet the DARPA cost objectives, the cost of growing and harvesting algae must be reduced by more than an order of magnitude over existing processes.

3. Identifying **economic processes for the extraction of oils from cellulosic biomass**. The molecular bonds in cellulosic biomass are much more robust against the commercial processes used for breaking down the bonds in seed crops (corn, sugar cane, etc.). Existing processes used to convert seed corn, sugar cane, and other food crops to biofuels are not adequate for extracting oils from cellulosic biomass. However, cellulosic biomass is the most abundant source of biomass and the potential "gallons/acre" extractable from cellulosic biomass is much higher than that extractable from food crops.

4. Identifying **commercially viable "co-products."** The processes for extracting oils from algal and cellulosic biomass are not 100% efficient and will leave behind by-products that can be further processed into a variety of products (fertilizer, alternative fuels, etc.) that may have a marketable value of their own. The sale of these co-products may dramatically reduce the final end user price for JP-8 surrogate biofuels.

DoD Fuel Facts

In a speech at the Asia Security Summit in Singapore, June 2008, Secretary of Defense Robert M. Gates noted that DoD is "probably the largest single user of petroleum products in the world….Every time the price of oil goes up by $1 per barrel, it costs us about $130 million…."

(more)

He went on to explain that DoD spent $12.6 billion on jet fuel, diesel, and other fuels in 2007, with operations in Iraq and Afghanistan consuming $1.7 billion of that total. (American Forces Press Service article, "Military Looks to Synthetics, Conservation to Cut Fuel Bills," by Donna Miles, 6/6/08. Full article: http://www.defenselink.mil/news/newsarticle.aspx?id=50131)

PETROLEUM PURCHASES (FY06)

TYPE	THOUSANDS OF BARRELS*	PRODUCT COST ($M)
AVGAS	16	2.6
DISTALLATES & DIESEL	22,079	1,821.9
GASOHOL	45	4.4
JP-4	15,598	1,122.5
JP-5	14,424	1,240.1
JP-8	71,318	6,162.3
LUBE OILS	28	5.0
MOGAS (LEADED AND UNLEADED)	1,971	176.1
RESIDUALS	733	40.8
TOTALS	**126,212**	**10,575.7**

*One U.S. petroleum barrel equals 42 U.S. gallons
(Source: Defense Energy Supply Center FY 06 Fact Book)

Additional Resources

- Media point of contact: Jan Walker, DARPA, (703) 696-2404, jan.walker@darpa.mil .
- BioFuels – Alternative Feedstocks program website, http://www.darpa.mil/sto/chembio/biofuels_alternative.html
- BioFuels – Cellulosic and Algal Feedstocks (aka Alternative Feedstocks) program solicitation (November 2007), https://www.fbo.gov/spg/ODA/DARPA/CMO/BAA08-07/listing.html
- "Energy as a Tactical Asset," speech delivered by Dr. Doug Kirkpatrick at DARPA's 25th Systems and Technology Symposium (August 2007), http://www.darpa.mil/DARPATech2007/proceedings/dt07-sto-w-kirkpatrick-energy.pdf .
- BioFuels solicitation (July 2006), http://www.darpa.mil/sto/solicitations/BioFuels/
- DARPA BioFuels program website, http://www.darpa.mil/sto/chembio/biofuels.html
- Defense Energy Supply Center FY 06 Fact Book, http://www.desc.dla.mil/DCM/Files/FactBook_FY06.pdf

-END-