

QUESTIONS AND ANSWERS

PLEASE REFER TO THE GENERAL FAQs SECTION OF ARPA-E'S WEBSITE (<http://arpa-e.energy.gov/?q=faq/general-questions>) FOR ANSWERS TO MANY GENERAL QUESTIONS ABOUT ARPA-E AND ARPA-E'S FUNDING OPPORTUNITY ANNOUNCEMENTS. ADDITIONAL QUESTIONS SPECIFIC TO THIS FOA ONLY ARE INCLUDED BELOW. PLEASE REVIEW ALL EXISTING GENERAL FAQs AND FOA-SPECIFIC QUESTIONS BEFORE SUBMITTING NEW QUESTIONS TO ARPA-E.

I. Questions from the REUSE Blog:

Q1. In 2013, China began restricting imports and in 2018, completely banned several types of imported waste, including plastics. This action greatly affected recycling industries worldwide. How has this specifically impacted the U.S.?

ANSWER: After China banned almost all waste imports in 2018, many countries, including the U.S., began to divert their plastics to new destinations in Southeast Asia. These new destinations soon began to follow China's lead. Countries including Malaysia and Vietnam have cut back on plastic and paper imports. As a country, we need to take more responsibility about our own plastic and paper waste, which now is ending up in landfills.

Plastics and paper sent to landfills come from diverse sources, and estimates for the amounts vary. The REUSE program is focusing diverting materials sent to landfills from industrial facilities and the approximately 300 Material Recycle Facilities (MRFs), which sort "blue bin" recyclables. MRFs are currently sorting and baling a variety of plastic and paper grades, some of which are being landfilled since markets have collapsed.

Q2. ARPA-E has been looking at several Waste-to-Energy (WTE) technologies. What are some of WTE's important areas?

ANSWER: ARPA-E is seeking novel ideas and transformational technology in the following areas:

- a) Converting Solids Waste to Energy-Intensive Materials seeks technical pathways that improve the economics of waste-to-materials & energy processes. Details from the Workshop in November are at <https://arpa-e.energy.gov/?q=events/converting-solid-waste-energy-intensive-materials-workshop>
- b) REcycle Underutilized Solids to Energy (REUSE) technologies to produce a refinery blend stock and/or marine-grade bunker fuel oil (fuel oil used aboard ships) from mixed plastic/paper streams.
- c) Waste-To-Carbon (WTC) technologies such as enhanced/catalyzed hydrothermal carbonization of unsorted MSW and/or municipal wastewater (MWW, or sewage) to produce carbon/char-like products (This potential program is in early stages, so stay tuned for updates.)

Q3. What does ARPA-E aim to achieve with REUSE?

ANSWER: ARPA-E seeks to fund the development of technologies to convert high-energy materials—plastics (#1-7 polymers, rubber, and composites) and paper—currently going to landfills into a high-energy content liquid product. In particular, ARPA-E is interested in technologies that would lead to *economically viable* "liquefaction processes" that creates a high-energy content liquid that can be easily shipped to, and stored at, central locations. The liquid

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product could be used as a fuel blend stock or an intermediate for further conversion to fuels or chemicals. It does not need to be a highly refined fuel such as gasoline or diesel. The ultimate end products could come from up- or down-cycling the feedstocks. (Up-cycling is when the process converts feedstock into new products or better-quality products. Down-cycling is when the process converts feedstock (e.g., plastic) into a product that is of lower quality, functionality, or cost than what was originally used as feed.)

Deployment of multiple low-cost, simple, flexible, small-scale (100-500 ton per day) regional facilities using modular plants is anticipated. This scale is consistent with the sources for high-energy materials, which include the ~300 MRFs and industrial waste sources.

Q4. Why are the target high-energy materials limited to the items listed?

ANSWER: The larger objective of REUSE is to prevent plastic and paper from being sent to landfills. ARPA-E does not intend to compete with current recycling businesses. PET (polyethylene terephthalate) and HDPE (high-density polyethylene) bottles are economically attractive to MRFs due to the rising profitable markets resulting from newer recycling technologies. For example, PET can be recycled into new PET containers, carpet, clothing, packaging, automotive parts, etc. And many grades of paper are very attractive for recycling today.

However, the situation for other plastics and mixed paper is not as positive. The market for “#3-7” plastics (PVC, LDPE, PP, and PS, or polyvinyl chloride, low-density polyethylene, polypropylene, and polystyrene, respectively, as well as non-categorized plastics) has effectively collapsed due to bans by waste-importing countries. Recently the price of mixed plastic dropped to zero.¹ Many MRFs do not accept #3-7 plastics, and the low price has led some communities to suspend their collection of them.² Similarly the price for mixed paper is now negative.

Q5. Considering that recyclers were willing to ship these same materials overseas, is using small-scale regional facilities to recycle the plastics economical?

ANSWER: REUSE is focused on screening technologies that can work at small scale. Plastic and paper wastes are readily available in 100-500 ton/day quantities from MRFs; industrial facilities such as plastic processing plants, autoshredders, and tire recycling facilities; and agricultural sources, which produce about a half-million tons of plastic per year. Regional facilities minimize transportation and storage of waste materials, have smaller environmental footprints than large central plants, and help communities achieve sustainability goals locally, versus sending waste to neighboring communities or other countries. If REUSE technologies can work at a small scale, they will certainly be economical at larger scale, and smaller number of large-scale plants could be built near the largest population centers in the U.S.

Q6. Why is the focus of the liquid product fuel blend stock or an intermediate for further conversion to fuels or chemicals versus gasoline or diesel fuel?

ANSWER: Higher-grade end products like gasoline and diesel fuel have stringent fuel standards requiring high stable end product quality assurance. Plastic and paper feedstocks are known to be heterogeneous and varying in terms of the components. Producing products with tight specifications

¹ Update on International & Domestic Recycling Markets, J Semrau, MRF Stakeholder meeting Oct 7, 2019

² How recycling has changed in all 50 states, WasteDive, Nov 15, 2019

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from highly variable feeds at a small facility will require high capital and operating costs. It's more economical to produce intermediates, and ship these to large downstream facilities that already have the necessary separation and upgrading equipment.

Q7. Why is REUSE not encouraging proposals for pyrolysis (decomposition brought about by high temperatures), torrefaction (a mild form of pyrolysis) solvolysis (a chemical reaction in which the solvent is one of the reagents and present in greater excess than required for the reaction), and hydrothermal liquefaction (a process in which hot compressed water is used to convert biomass a liquid biocrude)?

ANSWER: There is extensive research that has been done on pyrolysis, solvolysis, and hydrothermal liquefaction of composites, plastics, cellulosic materials, and mixtures of plastics and cellulosic materials. Additionally, the Department of Energy's Bioenergy Technology Office (BETO) has invested resources and has active programs for these technologies. As a result, ARPA-E is not encouraging submissions for these processes, unless applicants can demonstrate a disruptive aspect of their technology, and/or a significant techno-economic breakthrough compared with the current state of the art.

Q8. If I have a team that can provide either testing or process modeling and techno-economic analysis but not both, is there still an opportunity for me to participate?

ANSWER: ARPA-E is encouraging proposals from teams that have interesting technologies. ARPA-E can assist applicants who need access to process modeling and/or costing tools.

II. Full Application Phase Questions:

Q9. I am writing for clarification to section 4. "Areas Specifically Not of Interest" in Appendix K "Recycle Underutilized Solids to Energy" of SOLICITATION ON TOPICS INFORMING NEW PROGRAM AREAS SBIR/STTR; DE-FOA-0001954. Specifically, is an engineered biocatalyst that transforms paper into crotonic acid ((2E)-but-2-enoic acid) and/or one of its esters responsive to this FOA?

ANSWER: Per the Section 2B of the REUSE Topic, ARPA-E is open to oxygenated compounds, including ketones, aldehydes, alcohols, and/or acids. However, the section also notes that ARPA-E discourages processes that produce high acid (acid number >0.5mg KOH/g) hydrocarbon liquids, and is not interested in high TAN (acid number >1.0mg KOH/g) liquids. REUSE discourages chemically unstable liquids (ie gum-forming liquids produced in some biomass pyrolysis processes), or processes that produce harmful co-products such as certain polycyclic aromatic hydrocarbons (PAH). Applicants with processes that produce these materials must discuss how these processes can be commercially viable.

Q10. Does REUSE requires a concept paper before the full application?

ANSWER: No. Refer to DE-FOA-0001954 Table 1 (*Targeted Topics*) and Appendix K for submission deadlines. Full Application content requirements are set forth at DE-FOA-0001954, Section IV.C. Be aware that this Technical Topic includes a unique Technical Volume template that is available on ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov>).

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Q11.1 In [Appendix K,] Section 2.C (Target Technologies) under “Autothermal pyrolysis/gasification”, it states “ARPA-E is not interested in processes that produce light gases or syngas that are subsequently converted to liquids using chemical or biological processes.”

Q11.1a Does this restriction apply just to this group of target technologies, or to all target technologies?

ANSWER: Targeted Topic K, Section 2.C addresses limitations for gasification processes. Section 4 outlines additional areas not of interest, including: *processes that require multiple conversion steps to produce a liquid product, ie gasification + Fischer-Tropsch.*

Q11.1b By “...subsequently converted to liquids...” does this mean that technologies are prohibited from producing light gases as a product that will be converted into liquids at a central facility, or does this mean that technologies are prohibited from having light gases as an intermediate product before producing liquids that are shipped to a central facility?

ANSWER: Per Section B of the Targeted Topic:

Ethane, propane, and butanes can be used as feeds for crackers, which produce plastic precursors. Consequently these products represent a path to “close the loop” on plastics recycling. However, transporting the lighter ethane, propane, and butanes is relatively more expensive, and their value is lower than heavier hydrocarbons.

Applicants must address economics associated with production of light gases.

Q12. In the REUSE white paper, under “other processes” an example of a disruptive process that ARPA-e would be interested in is provided. This example is a 2-step process (pyrolysis followed by dry/steam reforming). However, the FOA states in Section 4 that one area that is specifically not of interest is “Processes that require multiple conversion steps to produce a liquid product, ie gasification + Fischer-Tropsch”.

ANSWER: The aforementioned paper goes on to state:

For example, in a series of papers, Saad and Williams describe a 2-stage process for dry reforming waste plastics, with the goal of producing syngas. They were able to convert mixed plastics using CO₂ and steam, leaving open the potential to produce liquids instead of syngas.

The implication is that ARPA-E would be interested in directly converting mixed plastic, CO₂, and steam to a liquid product. As noted in the FOA (refer to Targeted Topic K, Section 4), ARPA-E is not interested in multi-step conversion processes.

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Q12.1 Is ARPA-e no longer interested in multi-step processes similar to the example provided in the white paper if they produce liquid fuel?

ANSWER: The FOA is specific about technologies not of interest (refer to Targeted Topic K, Section 4). Should there be a conflict between DE-FAO-0001954 and any other published information concerning this Targeted Topic the FOA will control.

Q12.2 If multiple conversion steps are prohibited, is it required that the waste must be converted to liquid in a single reactor, and any reactions occurring must occur under the same set of reactor conditions (temperature, pressure, flow rate, etc.)? In other words, must all of the reactions needed to produce an acceptable liquid occur simultaneously in a single reactor?

ANSWER: Multiple reactors are allowed.

Q12.3 If multiple conversion steps are prohibited, can different reactions occur sequentially in different sections of a single reactor (e.g., sections that have different temperatures and/or catalysts)?

ANSWER: Multiple conversions steps are allowed.

Q13. Would it be possible to extend the June 1 deadline of DE-FOA-0001954: Topic Recycled Underutilized Solids to Energy (Reuse) for ~2-3 weeks? Due to Covid-19, we have not been able to use needed facilities to collect our preliminary results.

ANSWER: The date and time for submission of Full Applications (i.e., June 1, 2020 at 9:30 am Eastern time) remains unchanged.

Q14. Is cost-share required for the topic K of DE-FOA-0001954 (Recycle Underutilized Solids to Energy)? ...

ANSWER: Cost sharing is not required under this Targeted Topic.