ARPA-E PROJECT SELECTIONS –
MODERN ELECTRO/THERMOCHEMICAL ADVANCES IN LIGHT-METAL SYSTEMS (METALS)

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These projects have been selected for negotiation of awards; final award amounts may vary.

METALS Technical Approach:
Primary Production - Aluminum

Lead Research Organization	Amount	Lead Organization Location (City, State)	Project Title Project Description
Alcoa, Inc.	$3,167,029	Alcoa Center, PA	**Advanced Aluminum Electrolytic Cell with Power Modulation and Heat Recovery** Alcoa will develop a highly advanced electrochemical system for low-cost and energy-efficient aluminum production. The current production process is energy intensive and loses a large amount of thermal energy. This advanced system will incorporate a high-cycle-life electrode that consumes less electricity while incorporating molten glass technology, which captures and reuses lost heat. If successful, Alcoa's electrochemical system will produce bulk aluminum that requires less energy with lower carbon emissions compared to the conventional process.
Gas Technology Institute (GTI)	$807,426	Des Plaines, IL	**Dual Electrolyte and Electrolytic Membrane Extraction for Aluminum Production** Gas Technology Institute (GTI) will develop a new electrochemical process that uses abundant, domestic ores to produce aluminum powder at near room temperature. Current domestic aluminum smelters use expensive foreign-sourced ore to produce aluminum, and operate at high temperatures with a significant amount of thermal energy loss. GTI's unique electrochemical process will require less energy and produce fewer carbon dioxide emissions than conventional smelters.
Infinium, Inc.	$1,000,000	Natick, MA	**Efficient Aluminum Production using Pure Oxygen Anodes** Infinium will develop an electrochemical aluminum extraction process using pure oxygen anodes. Infinium's anode technology will eliminate the toxic and corrosive contamination associated with conventional extraction methods, which will dramatically reduce energy losses, compared to conventional extraction processes. If successful, Infinium will deploy low-cost and highly energy-efficient aluminum-production cells in mini-mills or large plants.

METALS Technical Approach:
Primary Production - Magnesium

Lead Research Organization	Amount	Lead Organization Location (City, State)	Project Title Project Description
Pacific Northwest National Laboratory	$2,430,000	Richland, WA	**Catalyzed Organo-Metathetical Process for Magnesium Production from Seawater** Pacific Northwest National Laboratory (PNNL) will extract magnesium salt from seawater and convert it to magnesium using a metal-organic process. As seawater contains low concentrations of magnesium, extraction is traditionally a difficult, energy-intensive, and expensive process. PNNL's novel metal-organic process could enable more efficient magnesium extraction from seawater.
University of Colorado	$3,600,000	Boulder, CO	**Hybrid Solar/Electric Carbothermal Reactor for Magnesium Production** The University of Colorado will develop a new gasification process that uses concentrated solar power to produce magnesium and synthesis gas (syngas), a precursor for synthetic gasoline. The University of Colorado is using a novel quenching process to enable a gas-to-solid magnesium phase change. Current magnesium production is energy intensive and produces substantial carbon dioxide emissions. The University of Colorado's multi-faceted, renewable-energy-powered approach to magnesium production could reduce carbon dioxide emissions and lower costs, while also creating a synthetic fuel.
Valparaiso University	$2,301,379	Valparaiso, IN	**Solar-Thermal Electrolytic Production of Magnesium from Ore** Valparaiso University will develop a novel electrochemical cell that produces magnesium using solar-thermal energy and electrochemical processes. Valparaiso's advanced hybrid cell uses concentrated solar power for heating, minimizing the electricity requirement for magnesium separation. Valparaiso's system could reduce carbon dioxide emissions and electricity consumption compared to conventional magnesium production.

METALS Technical Approach:
Primary Production - Titanium

Lead Research Organization	Amount	Lead Organization Location (City, State)	Project Title Project Description
Case Western Reserve University	$675,573	Cleveland, OH	**Electrowinning Titanium Using Segmented Diaphragms** Case Western Reserve University will develop a single-step process to produce titanium from titanium salts using a multi-membrane electrochemical reactor. The thin, non-polar membrane technology prevents undesirable chemical reactions, enabling simpler conversion of titanium salts to titanium powder. Conventional titanium production methods are costly and energy intensive, limiting the widespread use of titanium, a versatile and durable structural metal. If successful, Case Western's single-step titanium production process will require one-third of the energy at a fraction of the cost, compared to conventional production methods.
iMetalx Group, LLC	$ 2,680,160	Pittsburgh, PA	**Electrowinning Titanium Using the Chinuka Process** iMetalx will develop an advanced electrochemical system to produce titanium from titania using abundant, domestic ore. Titanium is a versatile and robust structural metal; however, widespread adoption for advanced energy and consumer applications has been limited due to the high cost of production. If successful, the method developed by iMetalx's will reduce energy inputs and cost compared to current titanium production methods.
SRI International (SRI)	$907,853	Menlo Park, CA	**Direct Low-Cost Production of Titanium Alloys** SRI International will develop an advanced thermal chemical reactor that converts titanium and other metal chlorides to titanium alloys in a single step. The reaction between hydrogen and metal chlorides to produce titanium alloys would eliminate a series of expensive and energy-intensive melting steps used in current conversion processes. If successful, SRI's process will reduce the cost, energy consumption, and carbon dioxide emissions associated with titanium alloy production.

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Titanium Metals Corporation (TIMET)	$1,658,305	Henderson, NV	**Electrochemical Cell for Advanced Titanium Production** Titanium Metals Corporation (TIMET) will use a multi-step system that converts titanium ores to titanium using a series of thermo- and electro-chemical processes. Today, the widespread adoption of titanium, a versatile and durable structural metal, has been limited in advanced energy and consumer applications due to costly and energy-intensive production methods. If successful, TIMET's titanium production technique will significantly reduce cost by requiring one-third of the energy of conventional production processes.
University of Utah	$3,000,000	Salt Lake City, UT	**Novel Chemical Pathway for Titanium Production** The University of Utah will develop a new, simplified thermo-chemical manufacturing method to produce titanium from abundant, domestic ores. The new thermo-chemical process uses magnesium hydride for titanium extraction, requiring less energy than conventional methods and simplifying the extraction process. If successful, the University of Utah's process will significantly reduce energy inputs and costs compared to conventional titanium production methods.

METALS Technical Approach: *Primary Production – Thermal Storage*

Lead Research Organization	Amount	Lead Organization Location (City, State)	Project Title Project Description
Research Triangle Institute	$3,121,400	Research Triangle Park, NC	**High-Temperature Transfer and Storage System for Light Metal Production** Research Triangle Institute (RTI) will develop a thermal storage system for metal manufacturing facilities that can replace fossil fuels as a source of energy. RTI's technology uses a high-temperature heat-transfer system to store and transport thermal energy from a concentrated solar power system to a smelting reactor. If successful, RTI's system will enable the use of low-cost, renewable energy in domestic metals manufacturing.

METALS Technical Approach:
Secondary Production - Recycling

Lead Research Organization	Amount	Lead Organization Location (City, State)	Project Title Project Description
BlazeTech, Corp.	$274,026	Woburn, MA	**Hyperspectral Imaging for Identification of Light Metal Alloys** BlazeTech will develop an advanced sorting technology that uses the reflection from a specialized lamp to distinguish multiple grades of light metal scrap. Current light metal sorting technologies are inefficient and costly because they cannot distinguish between different types of alloys. If successful, BlazeTech's sorting technique will enable the recycling of typically discarded light metal scrap. This advanced reflection recycling process could reduce the energy consumption, carbon dioxide emissions, and costs associated with manufacturing light metal components.
Energy Research Company	$3,000,000	Plainfield, NJ	**Integrated Minimill to Produce Aluminum from Scrap** Energy Research Company (ERCo) will develop a new automated manufacturing process that can produce a finished product from mixed metal scrap in a single processing step. Unlike most current approaches, ERCo's process can distinguish and sort multiple grades of aluminum scrap for recycling. Aluminum production from scrap is currently a costly, energy-intensive process that creates significant carbon dioxide emissions. If successful, ERCo's new manufacturing process will enable the efficient and cost-effective sorting and recycling of scrap aluminum.
PARC	$992,129	Palo Alto, CA	**Electrochemical Probe for Rapid Scrap Metal Sorting** PARC will develop a new electrochemical diagnostic probe that identifies the composition of light metal scrap for efficient sorting. Current sorting technologies for light metals are costly and inefficient because they cannot distinguish between different metals. If successful, PARC's electro-chemical diagnostic probe will enable the recycling of typically discarded light metal scrap.

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Phinix, LLC	$608,863	Lexington, KY	**Electrochemical Extraction of High Quality Magnesium from Scrap** Phinix will develop a new electrochemical cell technology that can recover high-quality magnesium from aluminum-magnesium scrap. This technology could lower costs, energy inputs, and emissions from magnesium production, expanding its use in transportation industries. By recovering and reusing aluminum-magnesium scrap, Phinix's technology could reduce the need for manufacturing new, expensive primary metals while developing a sustainable and low-cost advanced manufacturing process.
UHV Technologies, Inc.	$416,189	Fort Worth, TX	**Low-Cost In-Line X-Ray Fluorescence Scrap Metal Sorter** UHV Technologies will develop an innovative X-ray fluorescent sorting technology that can distinguish multiple grades of scrap metals. Current light metal sorting technologies cannot distinguish between different types of alloy grades. If successful, UHV Technologies' sorting technique will enable the recycling of typically discarded light metal scrap by analyzing the electromagnetic spectrum emitted from scrap metal to enable the identification of the composition of different alloys for sorting.
University of Utah	$1,000,000	Salt Lake City, UT	**Electromagnetic Sorting of Light Metals and Alloys** The University of Utah will develop a new electromagnetic light metal sorting technology that can distinguish multiple grades of readily available scrap metals. Current light metal sorting technologies cannot distinguish between different types of alloy grades. If successful, the University of Utah's sorting technique will enable the recycling of typically discarded light metal by determining alloy grades, which could reduce the need for manufacturing new metals.

ARPA-E PROJECT SELECTIONS – REDUCING EMISSIONS USING METHANOTROPHIC ORGANISMS FOR TRANSPORTATION ENERGY (REMOTE)

These projects have been selected for negotiation of awards; final award amounts may vary.

REMOTE Technical Approach: *High-Efficiency Biological Methane Activation*

Lead Research Organization	Amount	Lead Organization Location (City, State)	Project Title Project Description
Arzeda Corp.	$1,000,000	Seattle, WA	**New Metalloenzymes for Methane Activation** Arzeda will leverage computational algorithms to engineer proteins for the creation of new synthetic enzymes to activate methane, the first step in producing a liquid fuel from natural gas. These completely new enzymes could transform the way methane is activated and will be more efficient than current chemical and biological approaches. If successful, Arzeda's technology could efficiently activate methane for cost-effective fuel production, and it could also be applied in a variety of other synthesis processes for fuels and chemicals.
Lawrence Berkeley National Laboratory	$3,500,000	Berkeley, CA	**Enzyme Engineering for Direct Methane Conversion** Lawrence Berkeley National Laboratory (LBNL) will re-engineer an enzyme to directly "methylate," or bind methane with, a common fuel precursor in order to produce a liquid fuel. Methylation, which does not require the input of oxygen or energy, is a new technique that has never been applied for efficient methane conversion. If successful, LBNL's process will enable low-cost, energy-efficient fuel production from natural gas.
MOgene Green Chemicals LLC	$1,449,327	St. Louis, MO	**Sunlight-Assisted Conversion of Methane to Butanol** MOgene Green Chemicals will engineer a photosynthetic organism for methane conversion that can use energy from both methane and sunlight. The use of renewable and readily available solar energy reduces equipment costs and greenhouse gas emissions. If successful, MOgene will develop a low-carbon-dioxide-emissions technology that produces a liquid fuel from natural gas and sunlight through efficient, low-cost biological conversion.

Lead Research Organization	Amount	Lead Organization Location (City, State)	Project Title Project Description
Northwestern University	$818,132	Evanston, IL	**Multicopper Oxidases for Methane Activation** Northwestern University will engineer an entirely new biocatalyst for highly efficient methane activation, the first step required to convert methane into a liquid fuel. Northwestern University will adjust and repurpose chemical properties within a certain class of natural enzymes that utilize copper to activate methane without the input of energy. Northwestern University's process could provide a low-cost solution to the first step of methane conversion, which has been a long-standing technological challenge.
Pennsylvania State University	$3,000,000	University Park, PA	**Methane-to-Acetate Pathway for Liquid Fuel** Penn State University will engineer a biocatalyst that makes use of methane as a co-reactant to generate chemical precursors of liquid fuels. Unlike other conversion approaches, this approach will explore reversing a naturally occurring sequence of reactions that produces methane from acetate. If successful, Penn State's technology will enable cost-effective, energy-efficient, and carbon-efficient conversion of natural gas to liquid fuels.
University of Michigan	$3,000,000	Ann Arbor, MI	**Anaerobic Bioconversion of Methane to Methanol** The University of Michigan will create a biological approach to activate methane, which is the first step in producing a liquid fuel from natural gas. Current approaches to methane activation require the addition of energy and oxygen, but the University of Michigan will engineer a methane-activation pathway inside of a methanogenic, or methane generating, microorganism that eliminates the need for supplemental inputs. If successful, the University of Michigan's biocatalyst will convert natural gas to a liquid fuel in a manner that is more efficient and cost effective than existing biological processes.

REMOTE Technical Approach:
High-Efficiency Biological Synthesis of Liquid Fuels

Lead Research Organization	Amount	Lead Organization Location (City, State)	Project Title Project Description
Coskata, Inc.	$941,726	Warrenville, IL	**Activated Methane to Butanol** Coskata will engineer methanol fermentation into an anaerobic microorganism to enable a low-cost biological approach for liquid fuel production. If successful, Coskata's technology will enable the rapid microbial conversion of methanol to fuel with high energy efficiency and low carbon dioxide emissions. In addition, Coskata's technology could integrate with other technologies that ferment methane to methanol.
Massachusetts Institute of Technology	$3,000,000	Cambridge, MA	**Single-Step Methane Activation and Conversion to Liquid Fuels** Massachusetts Institute of Technology (MIT) will develop a comprehensive process to directly convert methane into a usable transportation fuel in a single step. MIT's unique technologies integrate methane activation and fuel synthesis—two distinct processes required to convert methane that are typically performed separately—into one step. If successful, MIT's approach will result in a cost-effective approach to access natural gas in remote locations.
University of California, Davis	$1,500,000	Davis, CA	**Biosynthetic Conversion of Ethylene to Butanol** The University of California, Davis (UCD) will engineer new biological pathways for bacteria to convert ethylene to a liquid fuel. Currently, ethylene is readily available and used by the chemicals and plastics industries to produce a wide range of useful products, but it cannot be converted to fuels economically. If successful, UCD's new biocatalyst would enable cost-effective conversion of ethylene into an existing infrastructure-compatible fuel.
University of California, Los Angeles	$3,000,000	Los Angeles, CA	**Efficient Condensation Cycle for Methanol to Liquid Fuel** University of California, Los Angeles (UCLA) will develop a unique, non-natural pathway for highly efficient synthesis of fuel. Unlike other approaches, this new technology uses metabolic components that avoid carbon-dioxide-generating (decarboxylating) reactions. If successful, UCLA's technology will convert methanol to butanol efficiently, without emitting carbon dioxide, and it could easily integrate with advances in upstream methane activation.

Lead Research Organization	Amount	Lead Organization Location (City, State)	Project Title Project Description
University of Delaware	$3,000,000	Newark, DE	**Engineered Bioconversion of Methanol to Liquid Fuel** The University of Delaware seeks to engineer a synthetic methylotrophic organism to utilize new metabolic pathways to convert methanol into butanol while recapturing and reusing generated carbon dioxide. Unlike current bioconversion processes, The University of Delaware's technology offers greater efficiency without carbon dioxide emissions during the conversion of methanol to butanol, an infrastructure-compatible liquid transportation fuel.

REMOTE Technical Approach:
Process Intensification Approaches for Biological Methane Conversion

Lead Research Organization	Amount	Lead Organization Location (City, State)	Project Title Project Description
Calysta Energy	$797,646	Menlo Park, CA	**New Bioreactor Designs for Rapid Methane Fermentation** Calysta Energy will develop new bioreactors to enable efficient biological conversion of methane into liquid fuels. Unlike current technologies, Calysta's new bioreactor designs facilitate the delivery of methane to the biocatalyst for rapid fermentation of methane to transportation fuel. If successful, Calysta's technology would enable low-cost conversion of natural gas at remote sources, while reducing energy inputs associated with liquid fuel production.
GreenLight Biosciences	$4,500,000	Medford, MA	**Cell-Free Bioconversion for Access to Remote Natural Gas Sources** GreenLight Biosciences will develop a cell-free bioreactor that can convert large quantities of methane to fuel in one step. This technology integrates the rapid conversion rate of chemical catalysis into a single-step bioconversion process that does not use traditional cells. If successful, it could enable mobile fermenters to access remote sources of natural gas for low-cost conversion of natural gas to liquid fuel.
LanzaTech, Inc.	$4,000,000	Roselle, IL	**Bioreactor Design to Improve the Transfer of Methane to Microorganisms** LanzaTech will design a gas fermentation system that will significantly improve the rate at which methane gas is delivered to a biocatalyst. Current gas fermentation processes are not cost effective compared to other gas-to-liquid technologies because they are too slow for large-scale production. If successful, LanzaTech's system will process large amounts of methane at a high rate, reducing the energy inputs and costs associated with methane conversion.
Oregon State University	$630,867	Corvalis, OR	**Bio-Lamina-Plates Bioreactor for Enhanced Mass and Heat Transfer** Oregon State University (OSU) will develop an entirely new bioreactor design to enable low-cost conversion of methane to liquid fuel. OSU's ultra-thin, stacked plate system will improve the overall rate at which methane is transferred to biocatalysts. If successful, this new design could provide a low-cost alternative to current state-of-the-art methane bioreactors.