ARPA-E PROJECT SELECTIONS –
ROBUST AFFORDABLE NEXT GENERATION EV-STORAGE (RANGE)

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

Technical Approach: Aqueous

Lead Research Organization	Amount	Lead Organization Location (City, State)	Project Title Project Description
University of Houston	$760,000	Houston, TX	**Advanced Aqueous Lithium-Ion Batteries** The University of Houston (UH) will develop a battery using a novel water-based, lithium-ion chemistry that makes use of sustainable, low-cost, high-energy, organic materials. UH's new batteries will meet today's performance standards, while minimizing the potential impact of battery failure, thus offering manufacturers greater flexibility with regard to vehicle design.
EnZinc Inc.	$448,680	Emeryville, CA Washington, DC	**Dendrite Free Zinc–Air Battery** EnZinc, in collaboration with the U.S. Naval Research Laboratory, will develop a low-cost battery using zinc-air technology. Currently, zinc-air batteries are low power and offer a limited cycle life. EnZinc's porous, sponge-like zinc component prevents battery failure and enables high-power charge and discharge. If successful, EnZinc's zinc-air technology could reduce electric vehicle battery cost by more than half.
Princeton University	$962,389	Princeton, NJ	**Long-Life Rechargeable Alkaline Battery for EVs** Princeton University will develop unique alkaline battery chemistry for use in electric vehicles. Princeton's new technology uses abundant and inexpensive materials structured to enable a longer cycle life. If successful, Princeton's new alkaline chemistry could result in low-cost electric vehicle batteries that require minimal shielding and packaging.
University of California Los Angeles	$500,000	Los Angeles, CA	**Long-Life, Acid-Based Battery** The University of California, Los Angeles (UCLA) will develop a new acid-based, high-power, long-life battery that addresses the cycle life issues plaguing lead-acid batteries today. UCLA's battery could be combined with longer-range electric vehicle batteries to create a hybrid system that provides the power necessary for immediate response and acceleration. Additionally, this acid-based battery could also enable widespread adoption of start/stop technology that shuts

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			vehicles off when stopped to improve efficiency.
Jet Propulsion Laboratory	$2,834,335	Pasadena, CA	**Metal Hydride-Air Battery** Jet Propulsion Laboratory (JPL) will develop a new water-based metal hydride-air battery. When compared to the lithium-ion batteries currently available for use in electric vehicles, JPL's technology could offer significant cost and performance benefits due to the battery's lower mass and volume. JPL's new batteries have simplified packaging and design, are low-cost, and can be easily integrated into electric vehicles.
University of Maryland	$405,000	College Park, MD	**Multiple-Electron Aqueous Battery** The University of Maryland (UMD) will use water-based magnesium and hydrogen chemistries to improve the energy density and reduce the cost of an electric vehicle battery. Current water-based batteries have greater volume and weight compared to lithium-ion batteries, making them unsuitable for use in electric vehicles. If successful, UMD's water-based battery would achieve the performance standards of lithium-ion batteries, but would be smaller, lighter, and less expensive.
BASF	$4,000,000	Rochester Hills, MI	**Rare-Earth Free NiMH Alloy for EV Batteries** BASF will develop metal hydride alloys using new, low cost metals for use in high-energy nickel-metal hydride (NiMH) batteries. Conventional water-based NiMH batteries use rare earth metals and have a limited capacity that results in decreased driving range. BASF's rare earth-free components could offer both lower cost and improved capacity while maintaining many of the traditional characteristics of NiMH batteries, including simple design, low volume, and long service life.
General Electric	$899,958	Niskayuna, NY	**Water-Based Flow Battery for EVs** General Electric (GE) will develop an innovative high-energy chemistry for a water-based flow battery. Current flow batteries are generally low-energy density and only used for stationary energy storage. If successful, GE's new chemistry could enable the use of flow batteries in electric vehicles and improve driving range, cost, and reliability.

Technical Approach: Multifunctional

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Cloteam LLC	$3,500,000	Framingham, MA	**Low-Cost Electric Vehicle Battery Architecture** Cloteam LLC will develop an innovative system to join and package batteries using a wide range of battery chemistries. Unlike today's battery pack design, Cloteam's design enables flexible placement of battery packs to absorb and manage the impact energy from a collision. Cloteam's batteries could provide greater energy density compared to today's lithium-ion batteries, while reducing the costs associated with materials and processing.
Stanford University	$2,709,427	Stanford, CA	**Multifunctional Battery Chassis Systems** Stanford University will develop a battery that becomes a structural component of the vehicle chassis that protects the batteries in the event of a collision. Today's batteries are independent of the vehicle's structure and require heavy protective components. By serving as a structural component, Stanford's battery system could reduce vehicle weight, resulting in increased driving range.
University of California, San Diego	$3,498,067	San Diego, CA	**Multifunctional Battery Systems for Electric Vehicles** The University of California, San Diego (UCSD) will develop a new battery that can be built into a vehicle frame. Unlike current electric vehicle batteries that remain separate from the vehicle body, the new batteries and redesigned auto frame will become a part of the vehicle's support structure. This integration will lower cost and vehicle weight, while increasing driving range.
Arizona State University	$2,000,000	Tempe, AZ	**Multifunctional Cells for EVs** Arizona State University (ASU) will develop an innovative, formable battery that can be incorporated as a structural element in the vehicle. Unlike today's batteries which require significant packaging and protection, ASU's non-volatile chemistry could better withstand collision because the battery would be more widely distributed throughout the vehicle. The chemistry minimizes conventional protection and controls while enabling it to store energy and provide structure, thus making vehicles lighter and safer.
Penn State University	$543,495	University Park, PA	**Structural Battery Power Panels** Pennsylvania State University (PSU) will use a new fabrication process to build load-bearing lithium-ion batteries that could be used as structural components of electric vehicles. Today's

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			batteries are independent of the vehicle's structure and require heavy protective components. PSU's design would integrate the battery into structural components like floor panels, reducing vehicle weight and increasing driving range.
Purdue University	$500,000	West Lafayette, IN	**Impact-Tolerant EV Batteries** Purdue University will develop a lithium-ion electric vehicle battery pack that can better withstand impact during a collision. Unlike today's electric vehicle battery packs, Purdue's design would absorb shock from a collision and prevent battery failure while preserving the integrity of the pack. If successful, this impact-tolerant battery would reduce vehicle weight.

Technical Approach: Robust Non-Aqueous

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Quallion	$511,323	Sylmar, CA	**Lightweight Battery with Built-In Safety Features** Quallion will develop a lithium-ion technology with integrated safety features that can prevent local overheating before an entire battery becomes compromised. Electric vehicle batteries currently require thermal and mechanical safeguards to prevent overcharging, overheating, and cell damage. Quallion's battery will include new components to isolate damage and reduce the need for additional packaging and shielding.
Illinois Institute of Technology	$3,411,992	Chicago, IL	**Nanoelectrofuel Flow Battery for EVs** The Illinois Institute of Technology (IIT) will develop a flow battery for electric vehicles that uses a high-energy density liquid as its electrode. Flow batteries, which store chemical energy in external tanks instead of within the battery container, are generally low in energy density and therefore not generally used for transportation. IIT's battery will use a liquid electrolyte containing a large portion of nanoparticles to increase energy density while ensuring stability and low-resistance flow within the battery.
National Renewable Energy Laboratory	$999,088	Golden, CO	**Renewable Organics for Flow Battery** The National Renewable Energy Laboratory (NREL) will develop a new low-cost flow battery using organic energy storage materials. Flow batteries store chemical energy in external tanks instead of within the battery container and are generally low in energy density, so they are not generally used for transportation. NREL's electric vehicle batteries will use newly developed, renewable organic compounds to increase energy density and reduce cost.
Oak Ridge National Laboratory	$450,000	Oak Ridge, TN	**Impact-Resistant Electrolyte** Oak Ridge National Laboratory (ORNL) will create a battery technology that replaces conventional safety components with a material that changes from liquid to solid upon application of external force. Today's batteries include safety features that manage the spontaneous release of energy, but result in increased weight. ORNL's new impact-resistant materials would reduce the amount of shielding needed resulting in a decrease in the overall weight of the battery while ensuring safety.

Technical Approach: Solid-State

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Ceramatec	$2,966,691	Salt Lake City, UT	**Advanced, Planar Lithium/Sulfur Batteries** Ceramatec will develop a non-porous, high-conductivity ceramic membrane for lithium-sulfur batteries to minimize self-discharge, provide mechanical integrity, and extend battery life. Current porous separators contain liquids that negatively impact cycle life and have a low abuse tolerance. Ceramatec will demonstrate its innovative, low-cost, non-porous membrane with a prototype lithium-sulfur battery that also contains advanced electrolytes developed for this system.
Solid Power, LLC	$3,459,250	Louisville, CO	**All Solid-State Lithium-Ion Battery** Solid Power will develop a new low-cost, all-solid-state battery for electric vehicles with improved energy density and safety than conventional lithium-ion batteries. Solid Power's liquid-free cells use non-flammable and non-volatile materials that result in greater stability in the event of a collision or elevated temperature. Additionally, the use of low-cost, abundant materials in Solid Power's battery construction will result in lower material costs.
Bettergy	$387,572	Peekskill, NY	**Beyond Lithium-Ion Solid-State Battery** Bettergy will develop an inexpensive battery that uses a novel combination of solid, non-flammable materials to yield an energy density suitable for modern electric vehicles. Today's electric vehicle batteries require costly materials and expensive safety architectures. In contrast to today's electric vehicle battery chemistry, Bettergy's alternative will use low-cost energy storage materials combined with non-flammable components to produce batteries with comparable energy density, but enhanced strength and robustness.
University of Maryland	$574,275	College Park, MD	**Solid-State Lithium-Ion Battery with Ceramic Electrolyte** The University of Maryland (UMD) will develop ceramic materials and processing methods to enable high-power, solid-state, lithium-ion batteries. While most lithium-ion batteries are liquid based, solid-state batteries have a greater abuse tolerance that reduces the need for heavy protective components. UMD will leverage multi-layer ceramics processing methods to produce a solid-state battery pack with lower weight and longer life.