2024

ENERGY ASSET TRANSFORMATION

PROJECT PORTFOLIO

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

DISCLAIMER

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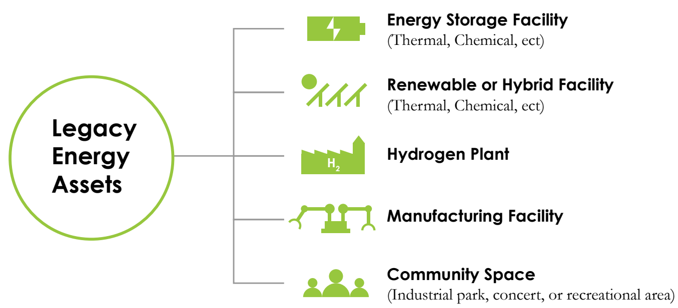
INTRODUCTION

The Energy Asset Transformation Program is focused on leveraging and transforming legacy energy assets into clean energy applications. These efforts represent some of the most promising opportunities to unite private sector and energy community interests in places where employment and opportunity are on the decline. Transforming these existing energy assets to clean energy and manufacturing uses is essential to address climate change and achieve a sustainable future. These transformations will require technological advancements, as well as careful integration of workforce, environmental, social justice, and safety considerations.

Legacy energy assets can be transformed into high-value opportunities such as energy storage facilities, renewable or hybrid facilities, hydrogen plants, clean manufacturing facilities, and community spaces. These industrial sites may offer access to a skilled workforce with knowledge of industrial operations, community relationships, access to transportation (rail lines, ports, waterways, highways), transmission and distribution infrastructure, electrical interconnect equipment and direct grid connections, and potentially existing site and permitting licenses, among other assets.



As innovative clean energy and manufacturing companies fan out across the country, it increasingly makes sense for the companies to choose locations in existing energy communities. In turn, transforming legacy assets addresses the potential resistance to the decommissioning of these assets and ensures that historic energy communities have a path forward. For energy communities, transforming energy assets can provide a variety of both short-term and permanent family-wage jobs, opportunities for worker retraining programs, access to local work that does not require relocation, and opportunities to work in cutting-edge technology sectors. Importantly, transforming energy assets allows communities to claim control of their narratives and become active participants in the energy transition. Additionally, many of these communities maintain a workforce that has knowledge of the industrial operations and community relationships that will be paramount to transforming each asset.

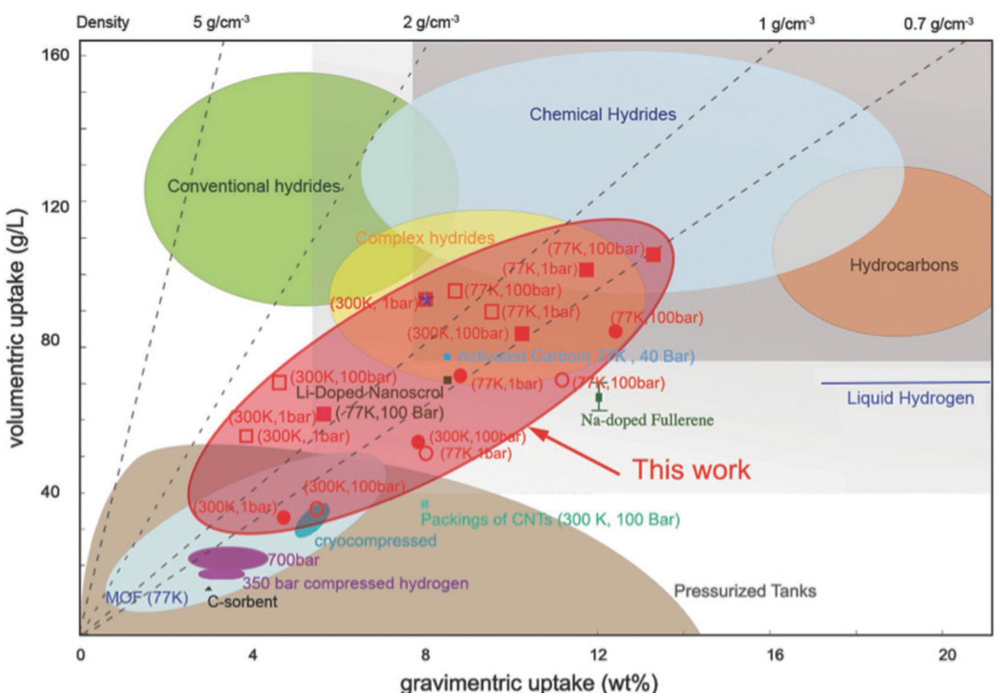
Initially, the Energy Asset Transformation Program will develop case studies of legacy energy assets across the United States that are being transformed. The program will fund concept development followed by pre-front-end engineering design (pre-FEED) studies where the assets can be transformed to use other sources of clean energy, such as solar, geothermal, wind, and nuclear sources, and the existing energy asset can be repurposed. The case studies and the pre-FEED work will serve as powerful examples for other communities to emulate and transition in a phased and methodical manner to achieve clean energy goals.

CHEMICAL TECHNOLOGIES

Low-Cost, Scalable Boron Nitride-Based Sorbents with Balanced Capacity-Kinetics-Thermodynamics for Hydrogen Storage in Fossil Fuel Power Plants

Performer	C-Crete Technologies, LLC
Award Number	FE0032010
Project Duration	03/01/2021 – 02/29/2024
Total Project Value	$ 312,500
Technology Area	Advanced Energy Storage

The overarching goal of this project is to demonstrate the feasibility of a new class of scalable, low-cost sorbents with an optimized balance of capacity-kinetics-thermodynamics for hydrogen storage and integration into fossil fuel power plants. The Phase I objective is to achieve full synthesis control over sorbent materials and their pore structure and to fabricate a small module followed by optimization and various structural, chemical, and thermal property characterizations. The Phase II objective is to evaluate the performance of hydrogen energy storage at both the material and system levels followed by the development of a conceptual process flow diagram, unit module, and performance models for integration into fossil fuel power plants. The technology may realize efficiencies of energy and time for the hydrogen-to-energy conversion, as only mild heat/pressure treatment will be required to rapidly desorb hydrogen for conversion to energy.

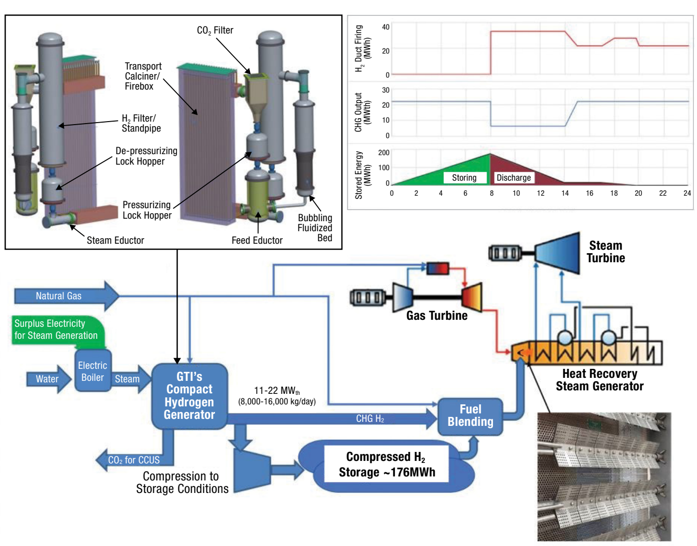


The proposed work in hydrogen storage technology leverages merger of energetic affinity and optimal geometry to impart both high gravimetric and volumetric hydrogen uptakes compared to other technologies.

Hydrogen Storage for Load-Following and Clean Power: Duct-Firing of Hydrogen to Improve the Capacity Factor of NGCC

Performer	**Gas Technology Institute**
Award Number	FE0032008
Project Duration	03/01/2021 – 12/31/2023
Total Project Value	$ 1,423,966
Collaborators	Southern Company; Pacific Gas & Electric; Electric Power Research Institute
Technology Area	Advanced Energy Storage

Gas Technology Institute (GTI), in partnership with Southern Company, Pacific Gas & Electric, and the Electric Power Research Institute, performed a Phase I conceptual study on asset-integrated production and intermediate-duration storage of greater than 150 megawatt-hours of energy in the form of "blue" hydrogen (H_2). The H_2 was produced from natural gas with integrated carbon dioxide (CO_2) capture using GTI's patented Compact Hydrogen Generator (CHG) technology. Stored H_2 was used for load-following in an existing natural gas combined cycle (NGCC) plant within Southern Company's fleet. The objectives of the study were to (1) perform a conceptual engineering assessment to define a system consisting of onsite H_2 production, storage, and integration within a Southern Company-owned NGCC plant, in which the stored H_2 will be injected into a duct burner within the heat recovery steam generator (HRSG) section; (2) perform the associated modeling to predict and quantify the load-following characteristics of the system; (3) obtain preliminary techno-economics and environmental performance of the system; (4) determine the risks and mitigation steps at the component/subsystem and integrated system levels; and (5) establish a project plan for conducting a potential preliminary front end engineering design (pre-FEED) study at a site that will be downselected from the 20 NGCC plants owned by Southern Company. Successful integration of energy stored as H_2 with an existing NGCC plant is expected to improve the capacity factor while reducing CO_2 emissions and improving system resiliency, dispatch, and reliability.



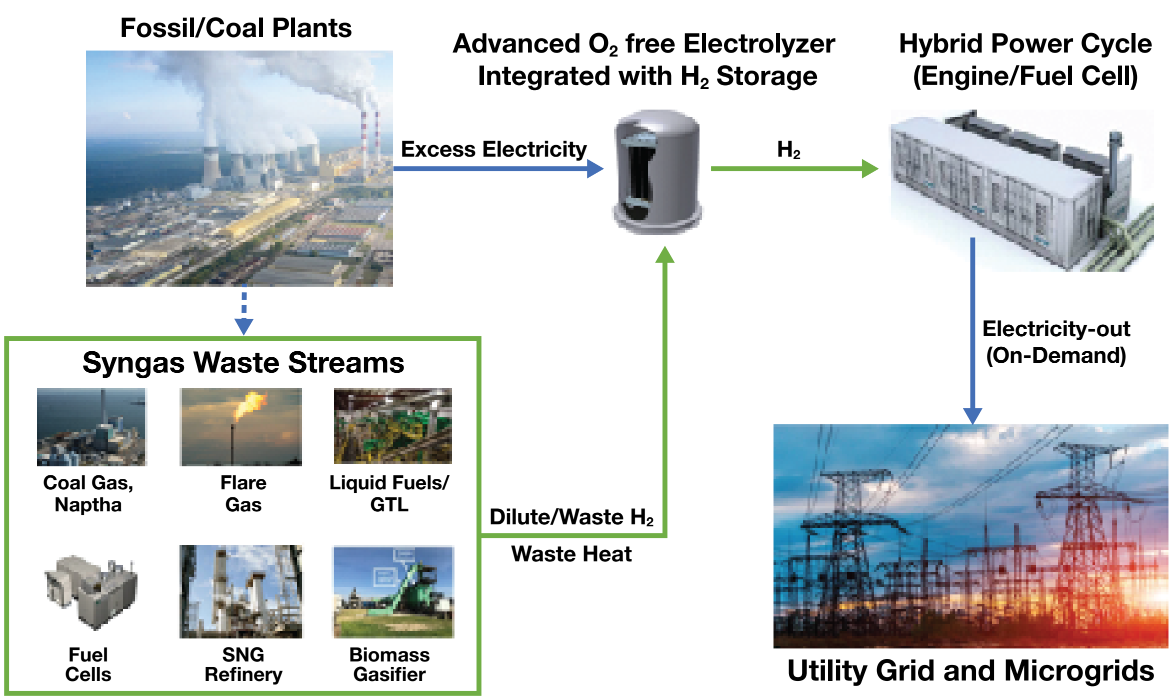
Hydrogen storage for load-following and clean power.

Advanced Oxygen-Free Electrolyzer for Ultra-Low-Cost Hydrogen Storage for Fossil Plants

Performer	**T2M Global, LLC**
Award Number	FE0032023
Project Duration	04/12/2021 – 02/29/2024
Total Project Value	$ 625,000
Technology Area	Advanced Energy Storage

T2M Global developed an advanced oxygen-free electrolyzer system (AES) to equip fossil plants with H_2 energy storage needed for load-following capability. T2M continued to scale up kilowatt (kW)-class AES technology to the 10-kW level for testing under simulated syngas conditions derived from a variety of fossil plants. T2M Global obtained input from Hawaii Gas at various stages from the identification of syngas streams to the design and deployment strategy development for the megawatt (MW)-class modules.

The MW-class AES module would use the excess electricity and waste heat from fossil plants to upgrade the dilute syngas streams to pure H_2 at higher pressures. The stored H_2 will be used to produce power on demand using a highly efficient hybrid power cycle. The AES targets a round-trip electrical efficiency of 80% and H_2 production at a cost of < $4/kg. Deployment of MW-class AES modules at fossil plants will reduce the greenhouse gas footprint and enhance their economic viability by generating additional revenue from currently stranded or underutilized resources

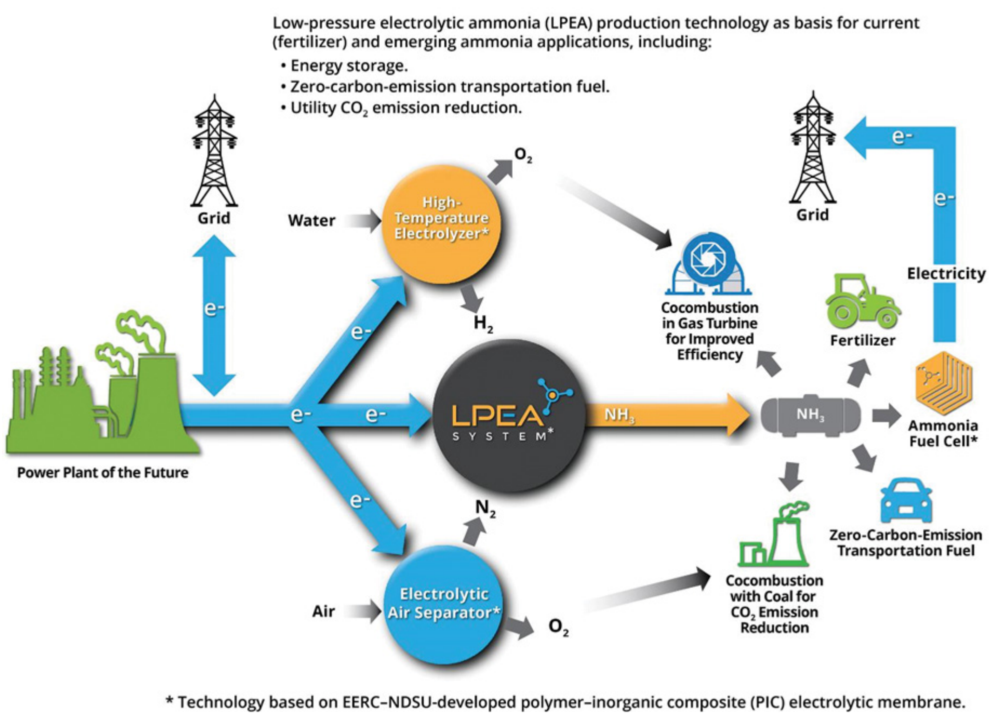


Use dilute syngas streams to produce higher value of H_2 and extend the life of fossil plants.

Ammonia-Based Energy Storage Technology (NH_3-Best)

Performer	University of North Dakota
Award Number	FE0032014
Project Duration	03/24/2021 – 12/23/2023
Total Project Value	$ 426,390
Technology Area	Advanced Energy Storage

Ammonia's unique set of chemical, physical, and economic properties make it the ideal energy storage medium for deployment at coal-fired power plants to reduce or eliminate the need for costly load following/cycling. In this project, the NH_3-BEST concept will be modeled, validated, and advanced from technology readiness level (TRL) 2 to TRL 3. This technology will enable electricity generation unit (EGU) accommodation of load fluctuations while operating within an optimal performance baseline output range, ensuring EGU operational efficiency and minimum degradation of materials, equipment, and performance due to load cycling-driven stresses. A basic model of the NH_3-BEST concept/subsystem, which comprises electrolytic ammonia production, storage, and conversion to electricity via a direct ammonia fuel cell, was defined and built using operational data from coal-fired utility plants. The model was utilized to evaluate and optimize NH_3-BEST performance when integrated with a power plant, establish NH_3-BEST round-trip energy storage efficiency, quantify power plant operational and economic benefits of NH_3-BEST integration, and establish NH_3-BEST performance requirements for commercial viability and deployment including storage capacity and operational ramp time. In addition to its carbon-free composition, high hydrogen content, low storage cost, and near-zero explosivity hazard, ammonia is a long-established globally fungible commodity. The highly developed ammonia industry represents an NH_3-BEST economic flexibility attribute since it opens possibilities for selling and/or buying ammonia to capitalize on market conditions or address production or supply challenges.



Economically Viable Intermediate to Long Duration Hydrogen Energy Storage Solutions for Fossil Fueled Assets

Performer	**We New Energy, Inc.**
Award Number	FE0032001
Project Duration	03/01/2021 – 12/31/2023
Total Project Value	$ 1,260,553
Technology Area	Advanced Energy Storage

The goal of this research project was to explore and advance an innovative hydrogen (H_2) energy storage system—the Synergistically Integrated Hydrogen Energy Storage System (SIHES)—with existing or new coal- and gas-fueled electricity generating units (EGUs) that are best suited for the intermediate- to long-duration energy storage needs (i.e., from 12 hours to weeks). Such a storage system enables the EGUs to operate at optimal baseload operation conditions. The added round-trip electricity (E)-H_2-E cost is $5-10/MWh, or less than 10% of the levelized cost of energy (LCOE) of today's fossil plant for 30 years of operation.

The prohibitive cost of this system is the primary barrier to applying today's energy storage technologies such as battery-based solutions for long-duration storage in fossil power plants. By reducing the added energy storage cost to less than 10% of the baseline fossil power generation cost, the proposed technology would be an economically viable solution for existing and new fossil power generation assets. Furthermore, by operating the fossil EGU and the energy storage technologies at their optimal conditions, our technology will benefit the asset owners by offering high flexibility and reliability and extended operational life of fossil power plants. Improving the capacity factor of power plants could result in more revenue.

H_2 storage tank.

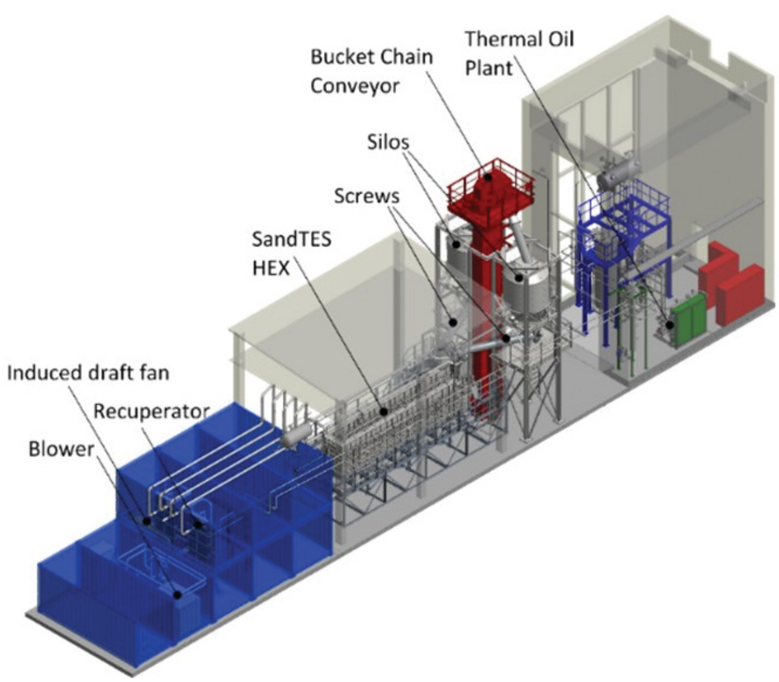
THERMAL TECHNOLOGIES

Sand Thermal Energy Storage Pilot Design

Performer	**Electric Power Research Institute**
Award Number	FE0032024
Project Duration	03/01/2021 – 12/31/2023
Total Project Value	$ 1,245,315
Technology Area	Advanced Energy Storage

The drive for a low-carbon future and the commensurate growth of variable renewable energy has led to a potential for grid instability and associated inability to provide dispatchable, synchronous power. Energy storage can alleviate these concerns. One promising vehicle for storage is sand-based thermal energy storage (SandTES) integrated with an operating fossil power plant. This strategy allows the plant to store energy in the system when less power is needed and provide power to the grid from both the operating fossil plant and the SandTES system when more is required. In Phase I, a feasibility study on the integration of a 10-MWhe SandTES system into Southern Company's coal-fired Plant Gaston was completed and in Phase II, a pre-front-end engineering and design (pre-FEED) was performed. The scope of work for the Phase I feasibility study consists of a conceptual study, a techno-economic study, a technology gap assessment, a project plan for Phase II, a technology maturation plan, and a commercialization plan.

The ultimate goal is to accelerate SandTES and its ability to be integrated with fossil power plants at low cost and risk. Achieving this goal will provide a critical option for dispatchable, synchronous energy storage. Energy storage combined with fossil energy assets offers a suite of benefits to asset owners, the electricity grid, and society. These benefits include more reliable and affordable energy, a cleaner environment, and stronger power infrastructure.



SandTES integrated system.

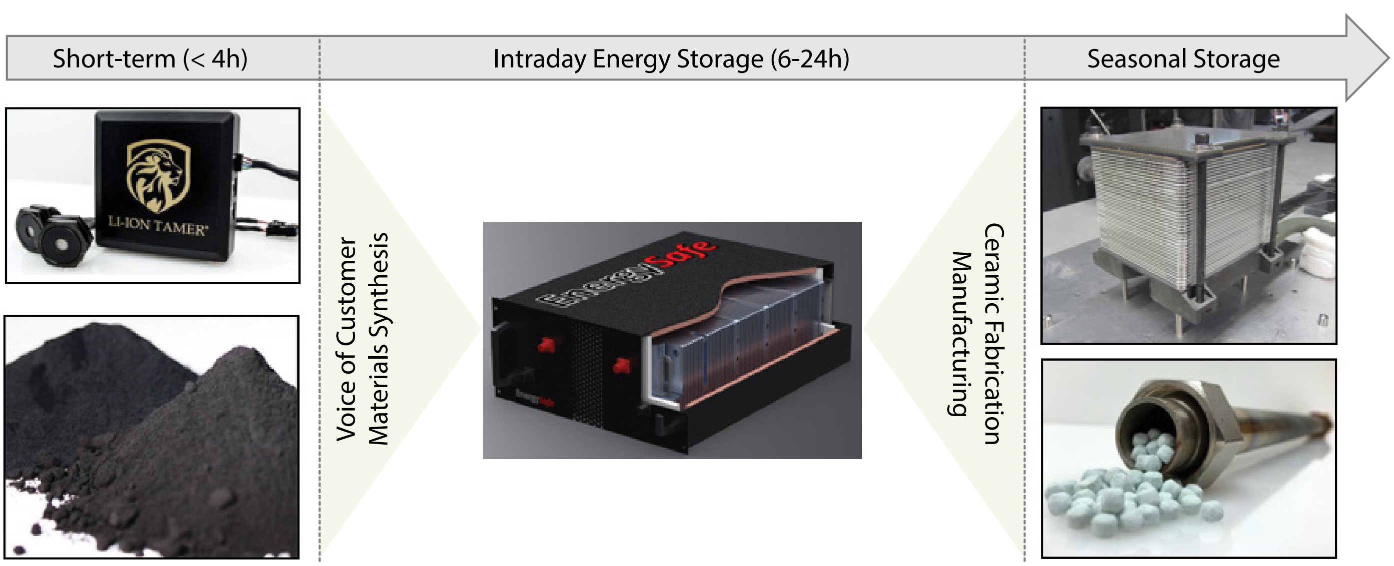
ELECTROCHEMICAL TECHNOLOGIES

Low-Cost Metal-Supported Metal Halide Energy Storage Technology

Performer	**Nexceris, LLC**
Award Number	SC0021566
Project Duration	02/22/2021 – 04/03/2024
Total Project Value	$ 1,356,500
Collaborators	Pacific Northwest National Laboratory; BRITE Energy Innovators
Technology Area	Advanced Energy Storage

Nexceris, LLC's goal is to advance the product readiness of EnergySafe™, a disruptive metal-halide energy storage technology that is ideally suited for fossil asset integration. EnergySafe™ systems can improve fossil asset utilization and environmental performance while improving grid stability and renewable integration. Nexceris advanced the maturity of the EnergySafe™ cell by tailoring its chemistry and design for EGU-integrated 6–24-hour storage, a critical unmet grid support need. In this Phase II project, Nexceris, in partnership with Pacific Northwest National Laboratory and BRITE Energy Innovators will accelerate the product readiness of EnergySafe™ culminating with independent testing and validation of a 5kWh module demonstration, to position EnergySafe™ for larger on-site demonstrations.

The EnergySafe™ cell design eliminates the high manufacturing costs associated with thick-walled, cylindrical electrolyte designs of the past that have prevented widespread adoption of the technology, while retaining the excellent safety and cycle life, insensitivity to ambient conditions, lower operation and maintenance costs, and supply chain based on low cost, recyclable, U.S.-sourced raw materials. Integrated with fossil EGUs, EnergySafe systems can use waste heat from the fossil asset to enhance overall efficiency.



Nexceris is engaged in technology development throughout the energy storage spectrum.

Titanium-Cerium Electrode-Decoupled Redox Flow Batteries Integrated with Fossil Fuel Assets for Load-Following, Long-Duration Energy Storage

Performer	**Washington University**
Award Number	FE0032011
Project Duration	03/01/2021 – 02/29/2024
Total Project Value	$ 626,215
Collaborator	Giner, Inc.
Technology Area	Advanced Energy Storage

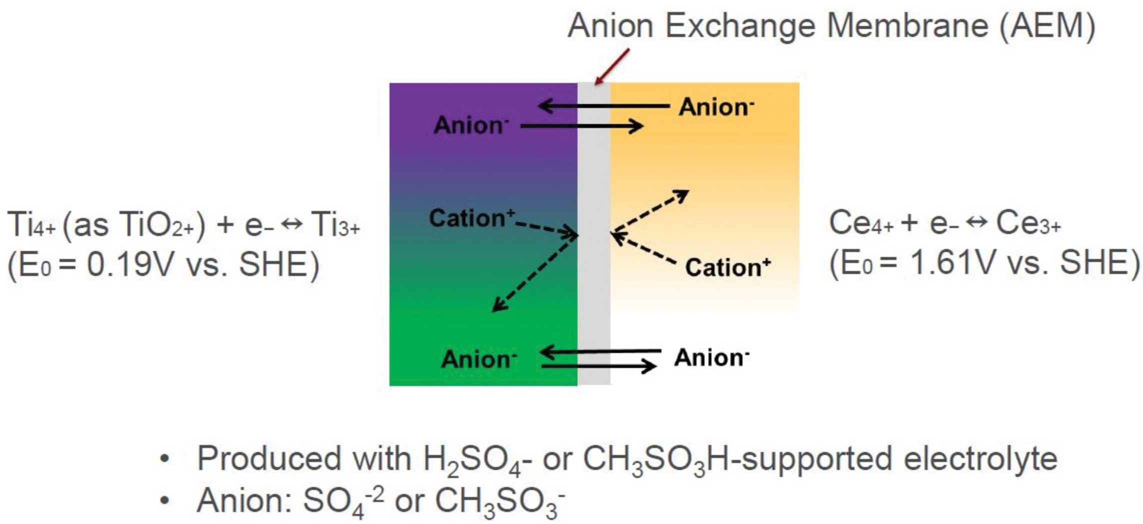
Operation of fossil plants at partial capacity with frequent cycling results in decreased efficiency and increased emissions, wear, and maintenance. The objective of this project is to advance the integration of a titanium-cerium electrode-decoupled redox flow battery (Ti-Ce ED-RFB) system with conventional fossil-fueled power plants through detailed technical and economic system-level studies, component scale-up, and research and development. The Ti-Ce chemistry has a clear pathway to meet the Department of Energy cost targets of $100/kWh and $0.05/kWh-cycle owing to the use of low-cost, earth-abundant elemental actives and incorporation of inexpensive carbon felt electrodes and non-fluorinated anion exchange membrane separators. With assistance from Giner, Inc., the team will scale up Washington University's existing laboratory Ti-Ce flow battery system to a kW-scale 3-5-10 cell stack with a current density of 0.5 A/cm2, a cycle duration of 48 hours, and less than 5% capacity loss during 1-week standby.

Cost and performance data from the RFB scale-up efforts will be incorporated into a detailed techno-economic assessment (TEA) of this storage technology situated within the fence lines of a fossil-fueled power plant to demonstrate the benefits of co-location to asset owners, grid operators, and the public. The TEA will consider both pulverized coal and gas-fired power plants with and without carbon capture. The path to commercialization of this storage technology will be enabled through market research, gap assessment, and technology maturation and commercialization planning. The resulting TEA and performance data are expected to show a reduction in risk and a lowering of potential barriers to wide-scale deployment of integrated grid-scale storage resulting in more secure, reliable, efficient, and cost-effective delivery of electricity with an increased share of renewables.

One tangible product of the proposed work will be a new power system economic modeling tool that will be made available to power plant owners. This tool will enable users to determine the best battery technology and size for their location and the electricity market. The tool may be used by developers of large-scale battery technologies to identify market opportunities and attract investment. The development of the 3-5-10 cell stack will provide a prototype scaled-up RFB that is cost-effective at the grid level. The project will also identify pathways to capital expenditure values of less than $500/kW (power) and less than $ 50/kWh (energy) for an annual production volume of less than 100 MW/yr and less than 1 GWh/yr, and a levelized cost of storage of less than $0.05/kWh-cycle, which will enable the widespread deployment of this technology solution.

For owners of fossil power plants, the addition of a cost-effective energy storage system will increase the value of the plant. Maintenance issues due to heavy cycling can be avoided, the life of the plant will be extended, fuel costs will be reduced because the plant will operate at a higher capacity factor, and operators will have increased decision-making ability. For example, during periods of low demand, the operator can opt either to turn down plant capacity or maintain steady operation and store excess energy.

The addition of energy storage provides the plant owner with additional revenue opportunities through arbitrage (storing energy when electricity prices are low and discharging when high) and by providing other valuable grid services such as frequency regulation and capacity reserve. Electricity consumers will benefit from a more stable, flexible, and secure power grid with improved load-following capability. Stranded renewable energy can be eliminated and emissions can be reduced through plant efficiency improvement and delivery of additional renewable energy to the grid. In summary, the integrated approach is of great importance in that it can lead to increased acceptance of intermittent sources while simultaneously improving the value and effectiveness of the existing fossil fleet, resulting in optimal grid performance while minimizing costs to consumers.



Ti-Ce electrode decoupled Redox flow battery. SHE: Standard hydrogen electrode.

ENERGY STORAGE INTEGRATION

Energy Storage Accessibility for Public Power Utilities

Performer	**American Public Power Association (APPA)**
Award Number	FE0032026
Project Duration	09/01/2021 – 08/31/2026
Total Project Value	$ 625,000
Technology Area	Advanced Energy Storage

The objective of this project is for the American Public Power Association (APPA) to employ its unique capabilities and position as a convener of community-owned electric utilities (public power utilities) to evaluate opportunities to integrate energy storage technologies with fossil power plants. APPA will consult with partner utilities to identify their needs and motivations concerning integrating energy storage with fossil power plants and use the findings to create a storage project maturity framework showing specific knowledge gaps by project stage. APPA will use this framework to create both educational resources and publications tailored to public power utilities and technical tools that build utilities' capacity for situation-specific project analysis (such as where to place storage units). APPA will also plan and/or host educational events such as conference sessions, workshops, and webinars. These events will be designed to allow experts in the field to engage with associated members on topics relevant to various maturity stages over the project period, advancing in maturity and complexity.

This approach will increase accessibility to energy storage projects and offer benefits to community-owned utilities of all sizes. Public power utilities that own and operate fossil-fueled assets, along with those that rely on them to ensure regional grid stability, will experience direct benefits from this work, while the development of optimal strategies and frameworks for implementing energy storage at community-owned electric utilities will assure mutual benefits for everyone connected to the electric grid. Adopting energy storage will improve the flexibility of fossil assets to contribute to grid reliability and resiliency while reducing damage from cycling and will result in enhanced environmental performance by enabling low-cost approaches to decarbonization.

AMERICAN PUBLIC POWER ASSOCIATION

Energy Storage

Performer	National Energy Technology Laboratory (NETL)
Award Number	FWP-1022469
Project Duration	07/01/2020 – 03/31/2024
Total Project Value	$ 1,517,260
Technology Area	Advanced Energy Storage

Cost-effective energy storage technologies are needed to provide reliable and low-cost energy services to U.S. industries and the public. More broadly, there is a need for baseload power generation with increased flexibility to assure short- and long-term reliability in the delivery of electric power as the use of intermittent renewable power generation increases. Fossil fuel plants have historically provided most of the baseload power on the U.S. electric grid. With a higher penetration of variable renewable power generation, coal power plants must adjust their power output as electricity demand fluctuates throughout the day. These cycling operations reduce the efficiency and lifetimes of the plants and increase harmful emissions. Energy storage technologies offer a potential solution to these problems. However, energy storage technologies for fossil plants are not yet developed and deployed at any meaningful scale in the United States. To accelerate impactful deployments, there is a need to better define energy storage use cases that use fossil energy and establish metrics for evaluating technologies and reducing the risk associated with newly adopted technologies.

This project will develop and disseminate energy storage knowledge and develop new metrics for energy storage when coupled with fossil energy assets. Both near- and long-term energy storage use cases and technologies will be assessed. Market and regulatory issues associated with integrating energy storage with fossil plants will also be assessed in this project.

Outreach for Advanced Storage Integration and Support (OASIS)

Performer	**National Rural Electric Cooperative Association (NRECA)**
Award Number	FE0032027
Project Duration	10/01/2021 – 09/30/2026
Total Project Value	$ 625,000
Technology Area	Advanced Energy Storage

The objective of the OASIS project is to assist in providing educational resources, outreach, training, workshops, and other means to electric cooperatives to empower them to integrate energy storage technologies with their generation systems. NRECA will also conduct coordination and outreach with its smaller electric generation utility members to facilitate awareness, transfer technology, and share best practices, lessons learned, and partnering on fossil energy projects. NRECA will enlist educational resources, available staff, case studies, guidelines, best practices, and training on common strategies for integrating energy technologies with fossil power plants and enhancing organizational capacities at utilities. NRECA will facilitate and convene meetings and events with cooperative utilities to define barriers to energy storage deployment and work with DOE and other stakeholders to overcome these barriers.

This project will result in better-informed electric utilities that will be positioned to participate in FECM's Advanced Energy Storage program as host sites for integrated testing at power plants as well as to adopt commercialized technology. Adopting energy storage will improve the flexibility and environmental performance of assets while reducing damage from cycling. It will also provide a pathway to decarbonization and contribute to grid reliability and resiliency.

ABBREVIATIONS

AES ....Advanced Oxygen-free Electrolyzer System

APPA.. .... American Public Power Association

CHG .... Compact Hydrogen Generator

CO_2 ....carbon dioxide

CT ....combustion turbine

DOE...Department of Energy

E ....electricity

EAT........................ Energy Asset Transformation (NETL)

EGU.................................... electricity generating units

FECM.. ... Office of Fossil Energy and Carbon Management

GTI ....Gas Technology Institute

GWh .... gigawatt-hours

H_2 ....hydrogen

HRSG ....heat recovery steam generator

kg .... kilogram

kW... kilowatt

LCOE..levelized cost of energy

MW... megawatt

MWe .... megawatt electric

MWh... megawatt-hours

NGCC...................................natural gas combined cycle

NH_3 .... ammonia

NH_3-BEST.......................ammonia-based energy storage

NRECA .....National Rural Electric Cooperative Association

OASIS............................. Outreach for Advanced Storage Integration and Support

pre-FEED ....preliminary front-end engineering design

RFB ....redox flow battery

SandTES .... sand-based thermal energy storage

SIHES .... Synergistically Integrated Hydrogen Energy Storage System

TEA .... techno-economic assessment

Ti-Ce ED-RFB ....titanium-cerium electrode-decoupled redox flow battery

TRL .... technology readiness level

U.S. ....United States

yr..year

NOTES

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