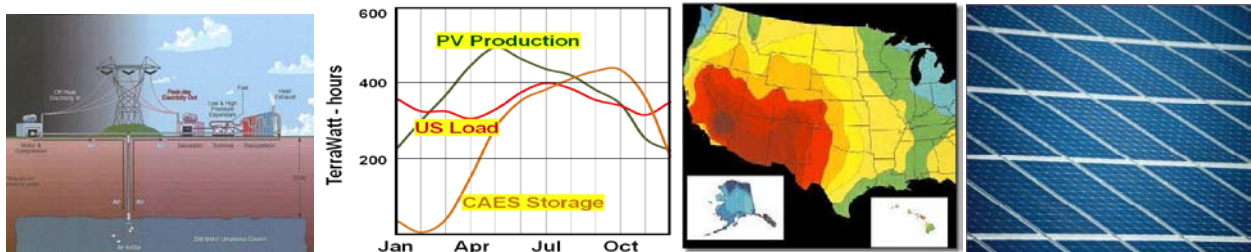


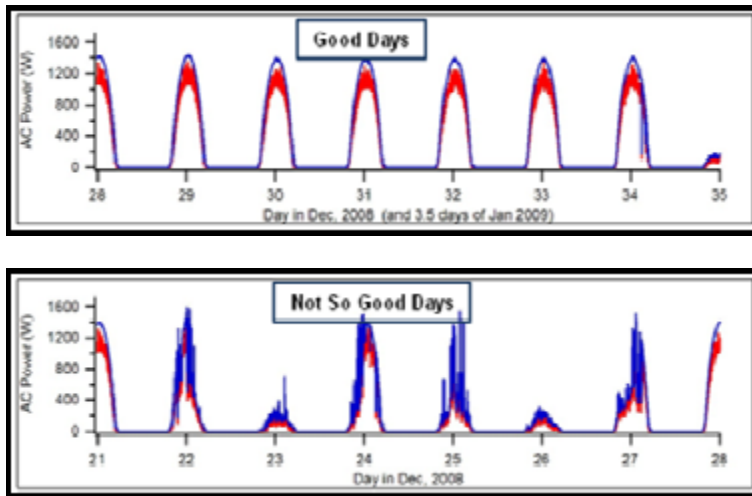
AzRISE Energy Storage Initiative



AzRISE's unique contributions are based on integrating new technologies and relevant economic and systems analyses together to create optimized, working systems that can operate in the real world by providing a reliable supply of energy at lower costs.

Background

Research at the Arizona Research Institute for Solar Energy at the University of Arizona addresses the goal of baseload through peak load electrical generation with solar energy and energy storage technology solutions.



Why energy storage?

- Diurnal or daily cycle
- Unpredictable intermittency
- Seasonal variation
- Production does not meet demand

Today, utilities must manage energy reserves to minimize higher costs associated with maintaining an oversupply of energy and the risk of blackouts from an undersupply or sudden loss of energy. This requires a real-time balance of supply and demand of energy into the grid not currently being met by coal and natural gas energy sources. These problems can be resolved with the proper mix of energy storage options that can accomplish four critical things:

1. Provide back-up power for an unexpected drop in sunshine or wind.
2. Provide electricity at night and in bad or calm weather.
3. Smooth out variations in renewable energy production on very short time scales.
4. Readjust seasonal variations in energy production to better match demand load. (For solar, move excess energy produced in the spring to the periods of high energy demand in summer and winter.)

Storage Solutions

AzRISE is engaged in a portfolio of storage solutions to address the need for reliable and effective delivery of solar energy. Storage solutions can be classified in several categories depending on the storage mechanism:

1. Mechanical: pumped hydroelectric and compressed air energy storage (CAES).
2. Chemical: batteries, hydrogen generation and fuel cells.
3. Electrical: supercapacitors.
4. Thermal energy storage for use in thermal engines (steam, Stirling and Brayton engines)

Each of these methods provides a range of operating characteristics that can be used to build the proper storage portfolio for any storage need in support of renewable energy generation. AzRISE has research, developments, and fiscal studies in all these areas through partnerships with faculty at the University of Arizona, other universities and industry.

A typical storage solution for single-building-level storage would include a mix of supercapacitors and batteries with additional storage in above-ground compressed air energy storage (CAES) if necessary. At the substation level

and utility-scale levels, we recommend supercapacitors, batteries and underground, higher capacity CAES with a novel application for thermal storage in support of CAES.

Critical characteristics of energy storage methods are fast response time and the long storage period. These are not available in a single technology and storage solutions must combine complementary technologies

Duration	Hydrogen	CAES	Thermal	Hydroelec	Flow cell	batteries	Supercap
4 mos and longer	+	+					
3 weeks	+	+					
3 days	+	+		+	+		
6 hours	+	+	+	+	+	+	
2 hours	+	+	+	+	+	+	
40 min	+	+	+	+	+	+	
10 min	+	+		+	+	+	+
20 sec				+	+		+
1 second							+

Long term

Intermediate

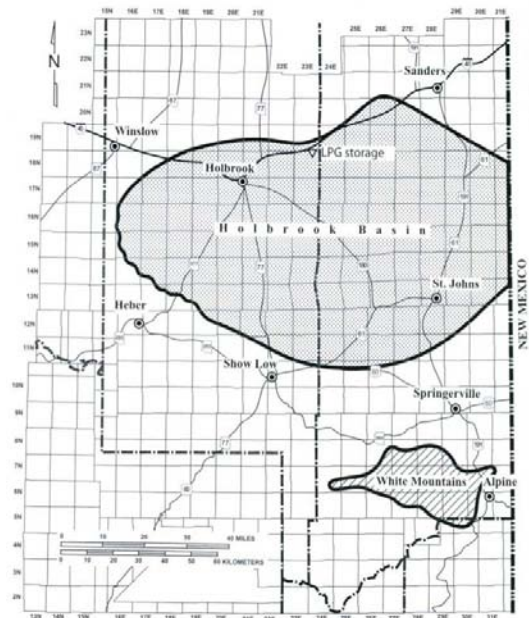
Immediate

Compressed Air Energy Storage (CAES)

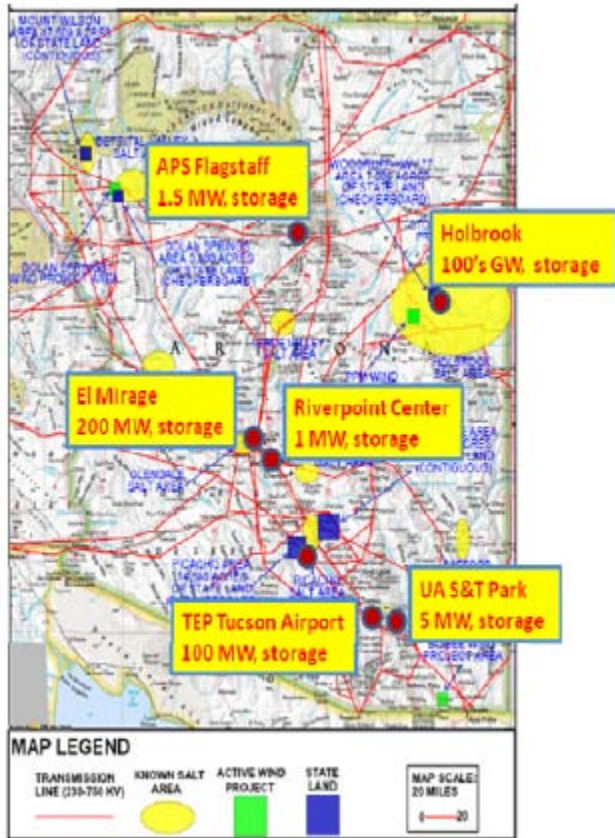
CAES involves compressing air and storing it in vessels either above-ground or below-ground. When there is no renewable energy available, the compressed air is heated slightly and released to drive turbines that generate electricity.

Storage capacity varies from minutes to years depending on the storage vessel used. Storage vessels can be solution-mined salt caverns, capped porous rocks that form aquifers, abandoned mines, depleted natural gas wells. Salt is a good storage medium for Arizona and the state has many large salt deposits that can store massive amounts of energy. Among these are the Luke Basin, the Picacho Basin, the Red Lake Basin near Kingman and the Holbrook Basin. The Holbrook Basin covers 3,500 square miles and is 300-600 feet deep. The Holbrook Basin can store enough energy to power the US's electrical demand for more than 60 days without recharge.

CAES holds the potential to transform and store large quantities of solar or wind energy for widespread transmission and usage, and AzRISE is partnering in the exploration of a range of CAES options. These include two demonstration sites, in Phoenix and Tucson, Arizona, dedicated to discovering options for storage that increase the overall efficiency of energy transformation, can help transform photovoltaic usage from individual rooftops to utility scale applications, provide back-up for other intermittent renewable energy sources, provide energy arbitrage and create a National Energy Reserve.



Specific Projects



- **Tucson Electric Power (TEP) and Tucson Airport Authority (TAA) Demonstration Facility** – (PV, CAES, batteries, systems integration, economics, new control systems, education and workforce training)
- **Flagstaff Community Demonstration** – Arizona Public Service (APS) AzRISE (distributed PV CAES, batteries, economics)
- **Riverpoint Solar Research Park** – Southwest Solar Technologies (SST), Univ. Phoenix, UA (test of new commercial CSP, CPV, PV, CAES, batteries, supercaps, economics, education and workforce training)
- **Science and Tech Park** – University of Arizona (UA), Bell, Solon (solar thermal, PV, thermal storage, education)
- **El Mirage** – SST (new CSP technology, CAES in salt caverns)
- **Holbrook** – Proposed DOE, AzRISE, UA, SST, AzREST, solar industry (CPV, CSP, PV, solar thermal, wind, biofuels, CAES in salt caverns, batteries, supercaps)

“Bright Tucson” Tucson Electric Power (TEP) and AzRISE demonstration site

The Bright Tucson project will build, commission, and operate a utility-scale test platform optimizing the use of 1MW of underground Compressed Air Energy Storage (CAES), 1 MW of lithium ion battery storage and 1.6MW of solar photovoltaic (PV) generation integrated with 41MW of demand response (DR) resources. The project will then improve state-of-the art resource optimization software to analyze the economic, security and reliability performance of these resources individually and in combination.

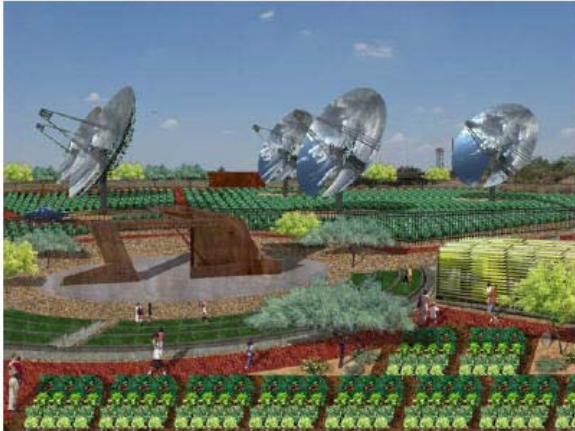
The Energy Resource Integration Platform (ERIP), will be integrated with the TEP utility grid and then ERIP will test the hypothesis that when integrated, and operating to utility industry security standards, these novel renewable and storage resources can add reliability and economic value to utility operations. These tests will create optimization scenarios for other utilities and researchers.

Riverpoint Solar Research Park

The project aims to build 2 pilot-scale facilities that integrate renewable-energy generation with energy storage, using a variety of sources and methods for each, and with land-use concepts, such as biofuels and agriculture, and with education and technician training activities. The project will use systems analysis and

advanced smart-grid/microgrids to optimize capacity, integration, cost and efficiency in delivering desired utility loads and advanced economic analysis/models to estimate the scaled cost of energy production.

Energy generation sources to be integrated are: flat-plate PV, single axis tracking PV, concentrated thermal and concentrated PV, solar trough and simulated wind. Energy storage methods to be integrated include: batteries (Li-ion, sodium sulfur and flow batteries), supercapacitors, compressed air energy storage (both underground and



above-ground), and other mechanical storage methods. Developed systems will be assessed for cost/benefit to identify areas where research might lead to a decrease in cost and/or improvement in efficiency supported by empirical modeling of technological change to determine effective policy alternatives. All components of the Center will contribute to research and education and will undergo individual performance analysis, as well as systems performance assessment. Education and training will also take place in a Visitor Center with student training and demonstration areas for public access.

Arizona Renewable Energy Storage Technology Consortium (AzREST)

AzRISE has convened a consortium to provide collective information and expertise to ultimately reduce the risk in implementing storage solutions while supporting successful resource planning with regards to a renewable/storage solution. The consortium is charged with participating in the design of assessment criteria in the research, development and deployment of long range storage technologies and other development issues defined by the consortium. This includes the assessment and collection of data on the performance of renewable energy and storage technology systems. The goal is to produce and enhance the technical and informational resources in areas such as:

- I. Research, Development and Demonstration
 - integration of scaled storage with renewable generation;
 - modeling tools to support resource and transmission planning for utilities;
 - in situ data and analysis of integrated renewable generation and storage system(s) in proposed demonstration site projects in Phoenix and Tucson, Arizona, education of key stakeholders and decision-makers for storage (e.g., government policy, utilities decision-makers, etc.).
 - II. Deployment
 - formation of a coordinated state-wide approach to integration of storage technologies in renewable energy generation systems around a common renewable energy and storage project at a site selected by the consortium.
- Members Include: Arizona Public Service Co. (APS), Tucson Electric Power (TEP), Salt River Project (SRP), Arizona Electric Power Cooperative, Inc. (AEPSCO), Western Area Power Administration (WAPA), University of Colorado, Boulder, Southwestern Power Group II, Northern Arizona University, University of Arizona, Arizona State University, Southwest Solar Technology (SST), guests: Arizona Corporation Commission(ACC), AZ Department of Commerce (DOC), Intertribal Council