PG&E's Compressed Air Energy Storage (CAES) Project

DOE ESSP Peer Review Conference
Washington DC

Pacific Gas and Electric Company

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Project Overview

300 MW, up to 10 hours storage*, in a porous rock reservoir in CA

Three phases:

1. Reservoir testing, plant design (currently funded)
2. Permitting, interconnection, bid and plant construction
3. Operations, Data Collection & Technology Transfer

Project Objectives

- Verify the technical performance of advanced CAES technology using a porous rock formation as the underground storage reservoir
- Integrate intermittent renewable resources
- Maintain emergency spinning/non-spinning reserve and perform volt-ampere reactive/voltage support

Phase 1 Funding:

PG&E Customers

* Final Project size will be determined by reservoir size / definition and by testing results, subject to management & CPUC approvals.

Major Achievements - Status

- **Site Selection/Permitting/Monitoring**
  - Long term site control agreements in place
  - All core drilling permits (2 sites)
  - Top site selected for Air Injection Test (AIT) based on detailed diligence and environmental screening
  - Environmental Assessment and FONSI issued by DOE for AIT

(http://www.netl.doe.gov/File%20Library/Library/Environmental%20Assessments/5-15-14-signed-PGE-FONSI.pdf)

  - EPA UIC (Underground Injection Control) permit issued for AIT

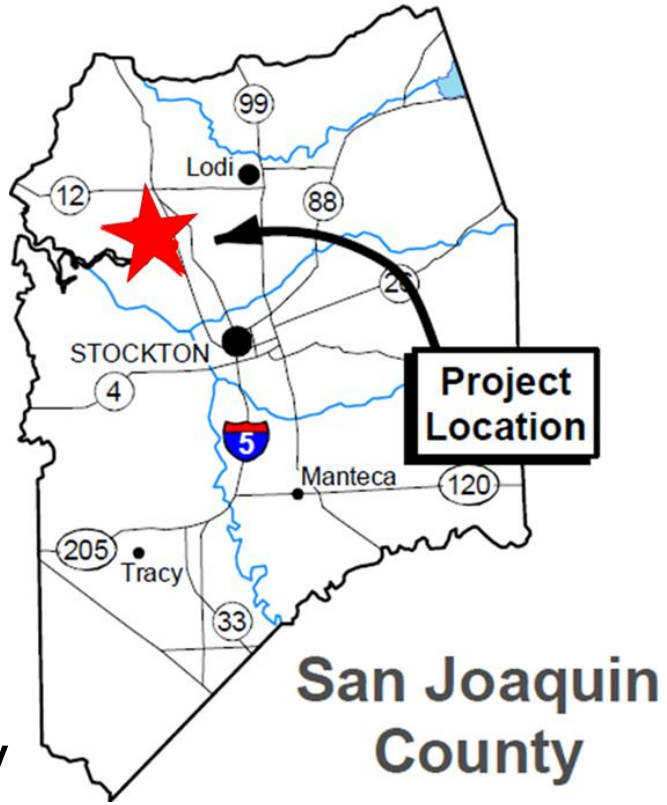
(http://www.epa.gov/region09/water/groundwater/uic-permits.html)

- **Engineering/Testing**
  - Screened over 100 reservoirs for technical feasibility
  - Completed core well contracting, drilling and demobilization (2 sites)
  - Core results: Excellent permeability, porosity and other geology
  - Preliminary engineering analysis of surface and subsurface technologies
  - Established feasibility of bifurcating Energy Conversion Facility (ECF) and reservoir/well pads
  - Reservoir model constructed utilizing 3D seismic data
  - Engineering, procurement and site prep complete for AIT

Lessons Learned - Site Selection

- **Geology drives key performance and development indicators**

- **Key drivers:**
  - Field size or depth (pressure)
  - Geologic properties (core results, DOGGR, etc.)
  - Field is not in production with minimal number of wells
  - Environmental and/or public policy
  - Ownership complexity/cooperation
  - Infrastructure (proximity to gas, power, water, etc.)
  - Bifurcation of ECF site selection



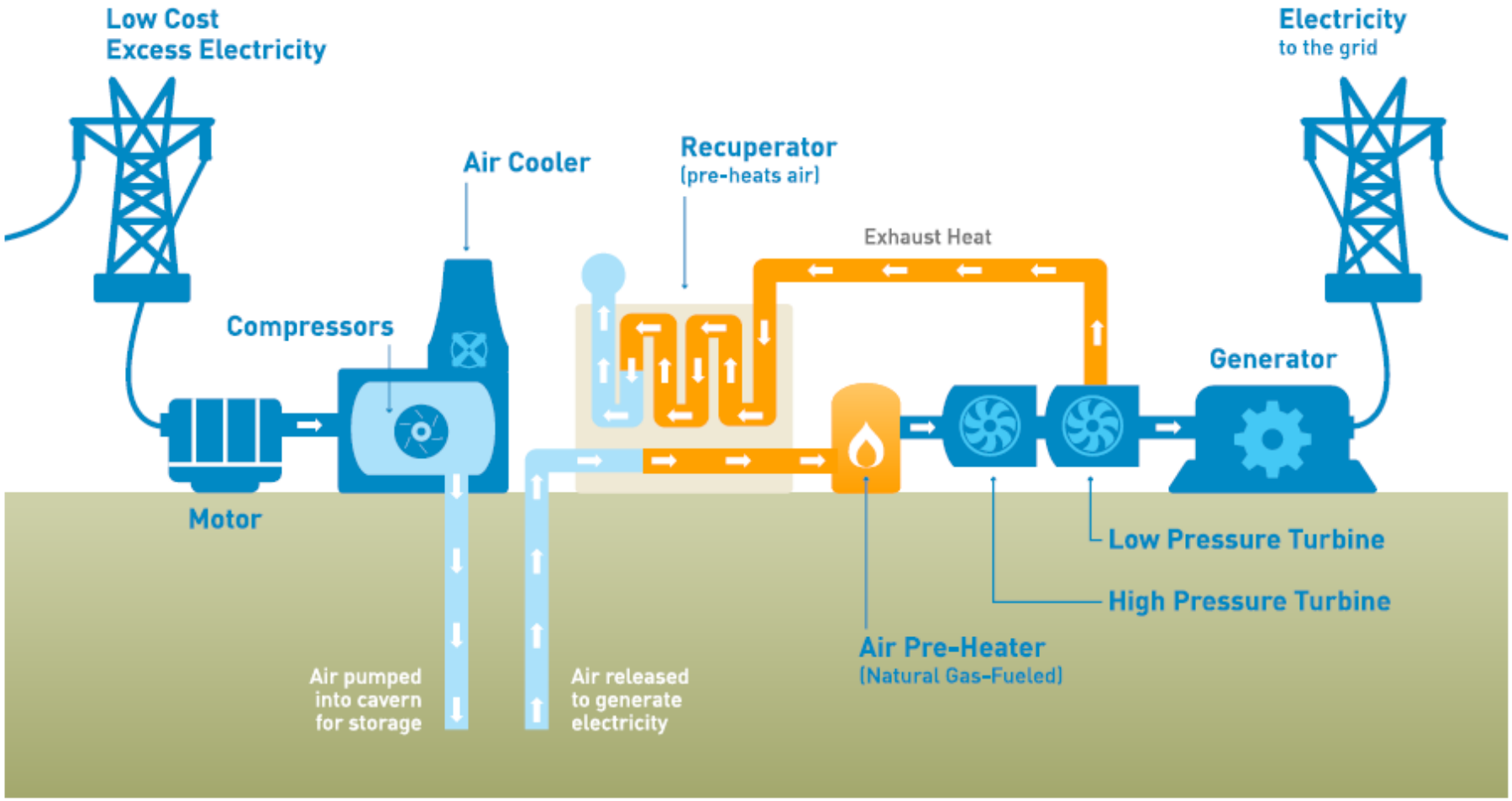
Core Drilling: Start to Finish

Reservoir Characteristics

What we were looking for and test results

- Important information learned from coring:
  - ➢Permeability – flow rate of air through the porous rock medium
  - ➢Porosity – measure of proportion of void space available for air storage in a given sandstone
  - ➢Other geologic properties
- Site 1 Results:
  - ➢Extracted 175 feet of core
  - ➢Initial core analysis indicates permeability in the range of 800-2,800 mD and porosity of 30-32%
- Site 2 Results:
  - ➢Extracted 115 feet of core
  - ➢Initial core analysis indicates permeability in the range of 800-2,800 mD and porosity of 30-32%

How does CAES work?



CAES Technical Overview

- Basis: Techno-economic evaluation of available surface and subsurface technologies and site specific boundary conditions
- Surface Plant technology: Next Generation of DR Alabama technology “SmartCAES”
  - HP and LP Fired Turbo-expanders with HHP
  - Use of recuperator (air-air heat exchanger) for heat recovery
  - Quick start capability (10 min to full load)
  - Low turndown ratio (Pmin) with minimal heat rate impact at low loads
  - Quick ramp rate (up and down)
- Subsurface Technology
  - Depleted natural gas reservoir >> 20-30 I/W wells
  - Likely water production/removal (various disposal alts)
  - Bifurcated reservoir/storage and ECF

Major Milestones

Phase 1 (Feasibility / Testing)	Projected Completion
Select Viable Sites Based on Desktop Analysis	Completed
Site control for top 2 sites	Completed
Complete Core Drilling & Analysis for 2 Sites	Completed
Select Air Injection Site	Completed
Conduct RFPs for Injection Test Contractors	Completed
Obtain NEPA & EPA Permit / Approvals for Air Injection Testing	Completed
NEXT	
Begin Injection Test	Dec, 2014
Injection Testing Complete	March, 2015
Issue RFO for Plant Ownership, Construction & Operation	Feb, 2015
RFO Responses Due	Oct, 2015
Complete RFO Process	July, 2016
Go/No-Go Decision	2016
Phase 2 (Permitting, Engineering, Construction)	2021

Next Steps

I. <u>Air Injection Testing (AIT)</u>

- **Build bubble at 1/10 scale**
- **Use of depleted O2 air for initial test**
  - ➢Followed by option for ambient air
- **Conduct injection/withdrawal tests**
  - ➢Mimic how the reservoir would be utilized for actual CAES operation
  - ➢Test results can be extrapolated and utilized to update the performance, operation and development cost models to be used by future developers and/or lenders
- **Measure the concentration of methane in the withdrawal stream**
  - ➢ Use results of AIT to validate existing models

II. <u>Investigate Native Natural Gas Mitigation Solutions (for a commercial CAES project)</u>

- Update model with AIT results to forecast entrained native gas profiles
- Work with DR and others to evaluate ECF technology solutions
- Evaluate reservoir development, operational, controls/monitoring alternatives