PG&E COMPRESSED AIR ENERGY STORAGE IN CALIFORNIA

Aparna Narang

Pacific Gas and Electric, San Francisco, USA

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The purpose of this manuscript is to provide an overview of Pacific Gas and Electric Company's (PG&E) initiative in evaluating the technical and economic feasibility of compressed air energy storage using porous rock reservoirs in California.

Keywords: compressed air energy storage

BACKGROUND

Pacific Gas and Electric Company (PG&E) was awarded funding from the U.S. Department of Energy (DOE), the California Energy Commission (CEC), and the California Public Utilities Commission (CPUC) to determine the feasibility of a 300 MW compressed air energy storage (CAES) facility utilizing up to 10 hours of storage in a porous rock reservoir. Currently, there are two utility scale CAES facilities operating in the world, and both utilize salt domes for their storage reservoir. Due to the geology in California and many other locations in the U.S., such underground storage features are not available. PG&E's CAES project is attempting to be the first commercial CAES plant to utilize porous rock formations, such as depleted gas reservoirs for the air storage. The identification, evaluation and testing of a reservoir, including preliminary engineering, environmental studies, and economic analysis, will take place over the next four years. Should the results of that testing and evaluation appear viable, and the appropriate approvals and funding is secured to move forward to construct a full CAES facility, it is anticipated such a facility would become commercially operational in 2021. The information provided in this manuscript provides greater detail on the reservoir selection and testing process, which began in February 2011 and is focused solely on evaluation of depleted gas reservoirs.

SITE IDENTIFICATION & SELECTION

Initial Site Selection

The reservoir identification process includes a variety of components that influence the selection of the appropriate depleted gas reservoir. An overview of the site selection process was provided in PG&E's poster presentation at the EESAT Conference on October 19, 2011. Since beginning this initiative, PG&E has evaluated approximately 124 potential fields in CA based on technical, environmental and other siting criteria. Specific reservoir evaluation criteria include porosity, permeability, sand thickness, size and pressure characteristics. The proximity to electric and gas transmission and environmental characteristics are significant factors as well.

The map below (Figure 1) shows a sample of abandoned or idle gas reservoirs in northern California in purple, a number of which have undergone preliminary evaluation by the PG&E team.

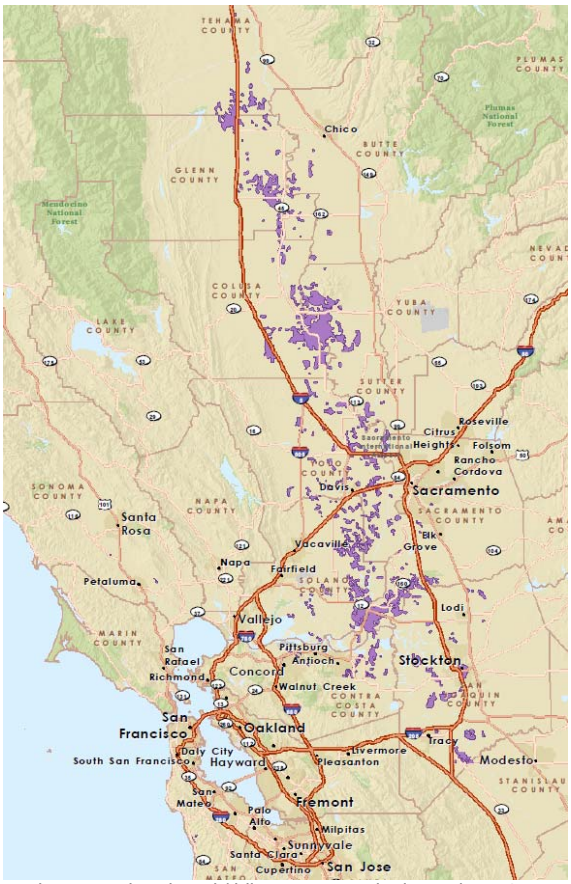

Figure 1: Abandoned / idle gas reservoirs in northern CA

The criteria developed to evaluate the potential reservoir fields is based on preliminary engineering studies, lessons learned from other subsurface investigations, and PG&E's experience with natural gas storage. The specific metrics utilized in the desk-top evaluation process were re-assessed in the preliminary analysis and are now as follows. Note that items in red font are considered "go / no-go" criteria:

Technical

- Original production greater than or equal to 4 BCF
- Permeability greater than 400 MD
- Porosity greater than 15%
- Discovery pressure between 1200 – 1800 psi
- Operating status: No longer operating or has less than 1 BCF remaining
- No oil or heavy hydrocarbons (ie. higher than C14)

production history
- Low or moderate water drive characteristics
- Sand thickness greater than or equal to 20 ft

Environmental / Siting

- Surface and below ground landowner attributes
- Proximity to gas and electric transmission
- Air district requirements
- Proximity to wetlands, sensitive species habitat, flood zones
- Proximity to sensitive receptors (residences, schools, parks, airports, scenic highways, etc)
- Land use (minimum of 30 to 40 contiguous acres above ground)

Based on these parameters, 14 fields passed the go / no-go threshold and 37 fields are still undergoing initial evaluation. Sites that pass the go / no-go threshold will continue to undergo more rigorous technical and siting screening in order to develop a ranking of potential short-listed sites. The primary goal of the site selection process of the PG&E CAES project is to select three sites to move into the reservoir testing phase.

Siting Evaluation Lessons Learned

The primary reasons why sites were eliminated during the initial screening process are as follows:
1. Field cumulative original production was too small,
2. Field was currently in production with a significant number of active wells,
3. Field was too shallow, hence pressure was too low, or
4. Field was too close to vernal pools, waterfowl refuges or had conservation easements on the property

Additionally, the project team is evaluating the economic characteristics of a proposed CAES facility. The framework for such an analysis is reflected in Figure 2 below:

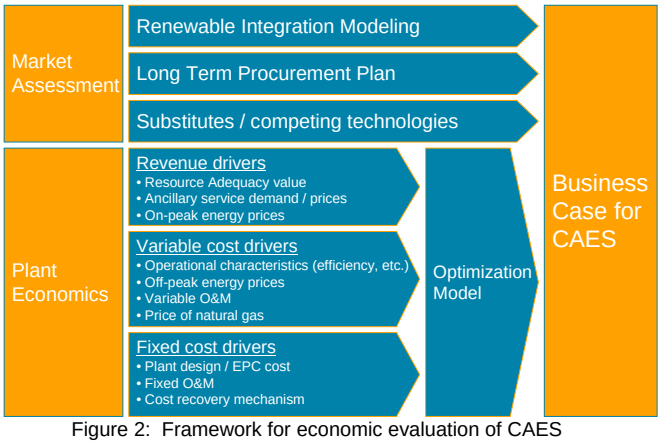

Figure 2: Framework for economic evaluation of CAES

Based on a very preliminary assessment of the economic variables identified in Figure 2, the results indicate that 4 to 6 hours of storage may be optimal, versus 10 hours as scoped in the original project plan. Due to the preliminary nature of this analysis the economic evaluation will undergo further refinement and deeper analysis throughout the course of this project including greater scrutiny of the following:

- Projected resource adequacy / capacity values for 2020
- Projected energy and ancillary service prices for 2020
- Projected peak & off-peak locational marginal pricing (LMP)
- Capital cost estimates for the facility based on additional engineering design
- Fixed and variable operating & maintenance cost estimates
- Evaluation of the market impacts of increasing penetration of renewables and integration

The results will influence potential reservoir and facility sizing, contributing to final site selection.

RESERVOIR TESTING PLAN

After the shortlist of potential sites is finalized (targeted for late 2011) and the appropriate site control and permits are secured, the reservoir testing plan starts off with drilling two test wells on the top three shortlisted sites. The core samples will be lab tested to verify that the reservoir characteristics match the screening criteria from the desktop analysis. Based on the results of the core analyses, along with other selection criteria mentioned above, one site will be selected for compression testing. Compression testing will include establishing an air bubble in the reservoir, followed by monitoring pressure levels and performing flow testing. The compression testing phase is estimated to take five to seven months to complete.

FUTURE WORK

This first phase of the CAES project is scheduled to take place over approximately 4 years. Through the remainder of 2011, the project team will be focused on continued desktop evaluation of the remaining reservoirs. By the end of 2011, the goal is to have completed the desktop analysis and selected the shortlist of three potential project sites. Ongoing throughout the course of the program is the economic analysis of the viability of a CAES plant in the California market.

In 2012 the major activities include securing site control for the three shortlisted sites, followed by the commencement of drilling for core samples later in the year. Additionally, a significant portion of the preliminary plant engineering and design will take place.

In 2013 the major activities include completing drilling and analysis of the core samples at three sites leading to the commencement of compression testing at one reservoir.

In 2014 the major activities include completion of compression testing, performing detailed environmental studies for the selected site, and completing the cost analysis and detailed engineering for the full facility.

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