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Compressed Air Energy Storage

The section on energy storage falls short because it does not cover Compressed Air Energy Storage (CAES) sufficiently. The fact is that CAES is a proven mechanical energy storage technology that is large-scale and can be operated as long-duration. R&D are needed to develop ways to feasibly implement CAES in California.

Given California's large inventory of abandoned natural gas fields (which to the report's credit are mentioned in the context of downhole heat exchangers in the geothermal section), we have an enormous opportunity to re-purpose natural gas reservoirs for CAES. This type of CAES is porous media CAES with compressed air stored in the pore space of the rock as opposed to cavern CAES which is carried out in large cavities/caverns in salt-dome geological environments.

Please see the attached document that fully outlines the enormous opportunity in California for CAES. And feel free to reach out to me for more information.

Additional submitted attachment is included below.

~~Utility-Scale~~ Energy Storage

Bringing New Value to California's Depleted Natural Gas Reservoirs

BERKELEY LAB

Overview

Lawrence Berkeley National Lab proposes the development of a new research and technology effort to repurpose California's depleted gas reservoirs for ~~utility-scale~~ storage of renewable energy using compressed air energy storage ~~and possibly hydrogen storage methods~~.

Why does California need this now?

For the last 30 years, production from California's conventional oil and natural gas reservoirs has been in steady decline, resulting in a large number of abandoned oil and gas wells and infrastructure at fields across the State. At the same time, California has experienced a growing need for ~~utility-scale~~ energy storage arising from the rapid expansion (and sometimes oversupply) of solar photovoltaic (PV) and wind electricity onto the electricity grid.

Senate Bill 350, passed in October 2015, requires retail sellers and publicly owned utilities in California to procure one-half of their electricity from eligible renewable energy resources by 2030, which will accelerate the deployment of intermittent renewable energy to the grid. During daylight hours, electricity produced by renewable sources commonly exceeds 50% of the total electricity load. At times, the amount of electricity from renewables even exceeds demand (not including demand supplied by baseload conventional sources), resulting in negative pricing and curtailment of this excess power from the grid. Each day, starting in the late afternoon, electricity demand soars when energy consumers return home and turn on lights and appliances, just as the supply of solar PV begins to drop. Energy providers make up for the simultaneous daily loss of solar PV and increase in demand by bringing more fossil fuel-generated electricity online from sources outside the State, a process known as ramping. If daytime-generated renewable electricity could be stored as compressed air in subsurface reservoirs for use in the evening, the need for ramping the supply of fossil fuel energy could be greatly reduced.

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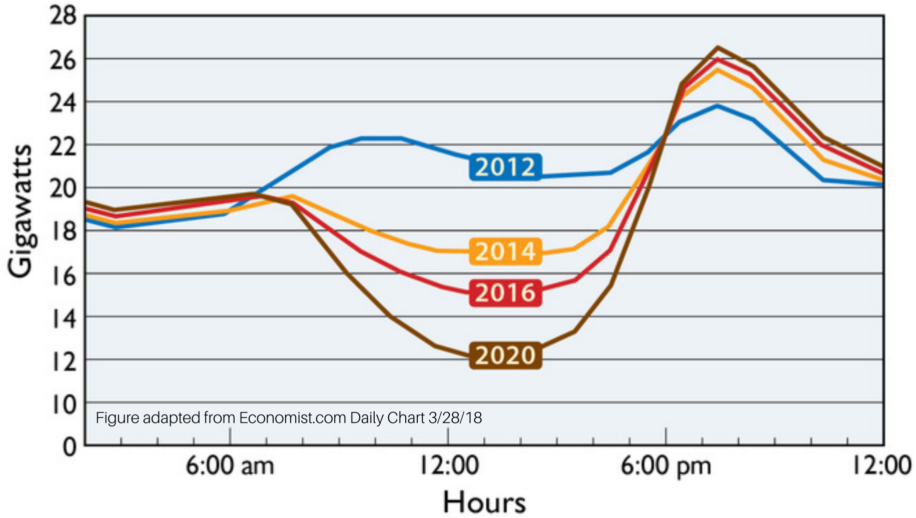
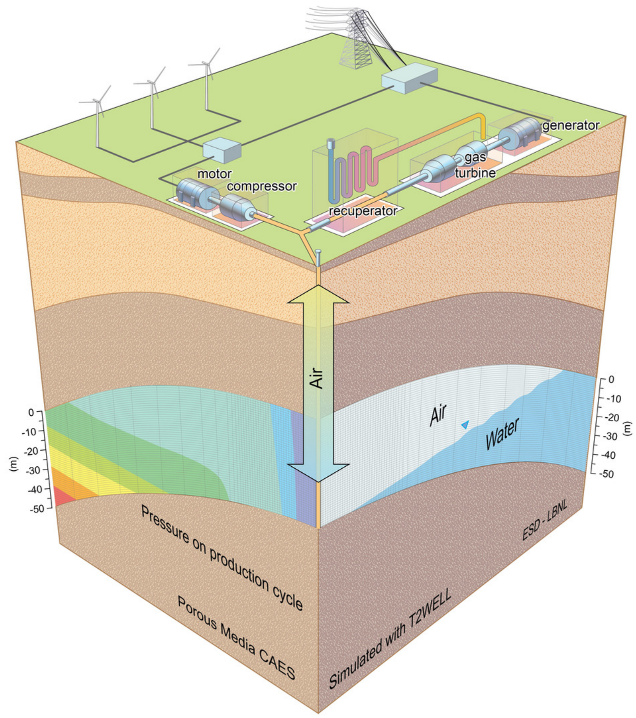


One of renewable energy's greatest challenges, the California "duck curve" shows the increasing daily supply of renewables over the years creates an increasing need for ramping conventional electricity starting around 4:00 PM each day.

Utility-scale energy storage during the day could eliminate the need for curtailment and fill all of this ramping demand and supply electricity throughout the night.

California's abandoned oil and gas infrastructure provides an excellent opportunity for meeting the State's demand for utility-scale energy storage. These depleted subsurface hydrocarbon reservoirs – made of porous rock formations – could be repurposed for compressed air energy storage (CAES) (and possibly hydrogen storage) of excess electrical energy from renewable sources. If successful, this could add a major new ~~utility-scale~~ energy storage capacity to California's electricity grid to help meet current and future demand.

Compressed air energy storage (CAES) is carried out using inexpensive excess renewable electricity to compress air and inject it into subsurface porous media structures. When power is needed, such as during the evening electricity demand period, the compressed air is withdrawn and delivered to turbines to generate electricity.



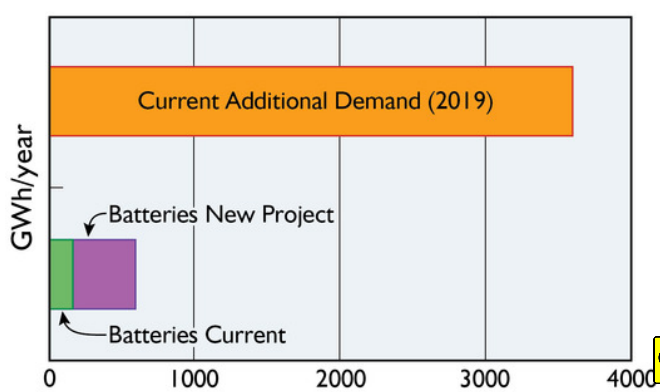
California's depleted conventional gas reservoirs provide an excellent opportunity for meeting the state's growing demand for ~~utility-scale~~ energy storage.

What are the limitations of current solutions?

The vast majority of ~~utility-scale~~ electrical energy stored in California is carried out by pumped hydro storage, the process by which water is pumped up into reservoirs at high elevation during periods of low demand using low-cost electricity, and then sent downhill through turbines to generate electricity during periods of high demand. Given its dependence on seasonal precipitation, pumped hydro storage capacity in California can vary significantly by year. For example, due to the high precipitation and snowfall of 2017, California's hydro increased four-fold to 4.5 TWh/yr. California's existing pumped hydro energy storage capacity is already fully subscribed without the growing supply of renewables. The fact is that California needs additional electrical energy storage of approximately the same capacity as the current pumped hydro capacity.

The best opportunities for pumped hydro are in locations where it currently exists – prized natural lands and recreational areas where it is unlikely that new or expanded hydropower infrastructure will be developed. Elsewhere, such as in the Mojave Desert, strong environmental opposition has prevented groundbreaking on a new pumped hydro project (EagleCrest/Next Era Energy Resources) since its first license application more than 25 years ago.

A large new battery project is starting in California at Moss Landing (PG&E-Tesla collaboration) with a target of providing 438 GWh/yr of power, which falls far short of the estimated 3.6 TWh/yr needed for storage. A comparison of projected battery energy storage supply in California (below) shows how utility-scale battery storage technologies are not projected to provide the energy storage needs of California in the near future.



Comparison of current energy storage supply and demand in California.

With fast-growing demand but limited solutions, California will need to create new pathways for meeting ~~utility-scale~~ energy storage demands. Given its climate leadership and ambitious mitigation goals and legislation, California will need to approximately double the State's available ~~utility-scale~~ electrical energy storage over the next two decades. Only by building new and reliable bulk storage approaches can California achieve fossil-fuel-free electricity by 2045 and satisfy new low-carbon emission legislation such as AB32 and SB100.

> California will need to approximately double its supply of ~~utility-scale~~ electrical energy storage over the next two decades if it is to achieve its emissions goals and legislative mandates.

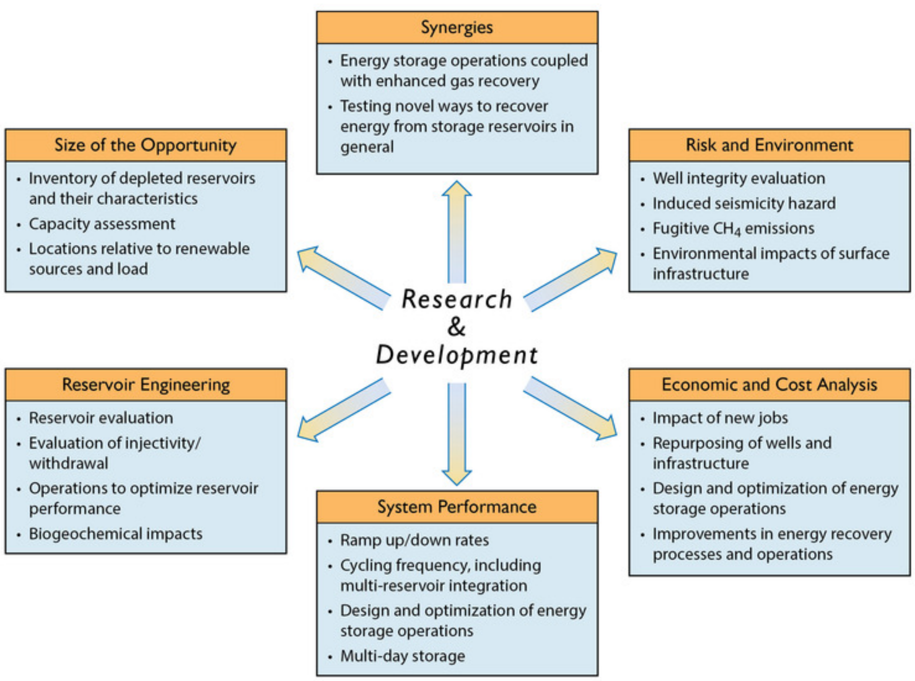
What will this project do?

Depleted natural gas reservoirs in California provide a tremendous untapped resource for subsurface storage of electrical energy. The idea of generating value from depleted hydrocarbon reservoirs by using them as energy storage reservoirs is not new. Underground natural gas storage (UGS) has been carried out for over a century often using depleted hydrocarbon reservoirs, so extensive knowledge and experience with subsurface porous media energy storage already exists.

What is new here is the simultaneous availability of vast volumes of proven reservoir storage space and the accumulated knowledge of how to carry out CAES (and possibly compressed hydrogen storage) in depleted reservoirs. Given the current demand for ~~utility-scale energy~~ storage, there is a new urgency to combine our existing knowledge with new research and development to repurpose these available subsurface resources. Depleted hydrocarbon reservoirs are uniquely well-suited for energy storage by virtue of their known trapping capacity, ability to contain high pressure gases, long record of well integrity, specific experience with the reservoir, and the existing built infrastructure of wells and pipelines. Given California's long history of industrial land use, there is also a wealth of skilled labor in our local communities and the potential to create new jobs and employment opportunities.

> Given the current demand for ~~utility-scale~~ energy storage, there is a new urgency to combine our existing knowledge with new research and development to repurpose available subsurface resources.

Porous Media-CAES (PM-CAES) has been studied extensively and tested recently in a depleted natural gas reservoir in the California delta near Stockton. In this California project, PG&E demonstrated technical feasibility for PM-CAES in the depleted natural gas reservoir but ~~could not find an~~ operator ~~to~~ build the plant ~~at a low enough cost~~. While there is little doubt that PM-CAES is technically feasible, a dedicated research effort is needed to reduce uncertainties that would allow economical ~~utility-scale~~ storage to be realized. This research effort could lead to widespread re-purposing of depleted gas reservoirs for utility-scale energy storage. To lower the barriers to energy storage in depleted reservoirs, a range of technical studies is needed as shown at right.



R&D needs related to re-purposing depleted gas reservoirs for ~~utility-scale~~ energy storage.

What resources are needed and how long will it take?

The capital cost for subsurface energy storage infrastructure is high, but there is no resource depletion involved and therefore the facilities can operate indefinitely generating very long-term revenues. The initial costs include well workovers or drilling new wells and building surface energy compression and recovery infrastructure. A proposed R&D effort for bulk energy storage can be divided into three major phases:

Phase I (1 year) – Initially, a roadmap would survey existing knowledge and identify stakeholders, define available resources and technical expertise in the State, and chart the major scientific questions that need to be addressed by the new R&D program.

Phase II (5 years) – Work with research, industry, and community partners in selection of sites for field trials, characterization and mapping geologic assets, economic analyses, performing feasibility storage and recovery studies, assessing environmental impacts, and generally carrying out a variety of research projects to develop innovations for improved PM-CAES.

Phase III (10 years) – Develop technology, carry out industry-sponsored tests at scale, perform grid integration, and build one to three demonstration facilities.

While there is little doubt that PM-CAES is technically feasible, a dedicated research effort is needed to reduce uncertainties that would allow economical ~~utility-scale~~ storage to be realized.

The need to double utility-scale energy storage

If we assume that every night there is a need to store an amount of electrical energy equal to the amount of solar PV generated during the day in California, we would need approximately 3.6 TWh/yr of energy storage.

$$10\ GW \times \frac{10\ hrs}{day} \times \frac{365\ days}{yr} = 3600\ \frac{GWh}{yr} = 3.6\ \frac{TWh}{yr}$$

This is approximately equal to the current electrical energy stored by pumped hydro which would still be needed for the same purposes it is used today. Therefore, we need to double the current utility-scale electrical energy storage capacity in California just to meet today's need. In the future, this need will grow as overall electricity demand grows and as the California climate and energy laws require more of our energy to be supplied by renewables. If not supplied by subsurface storage, how will we meet the demand for an additional 3.6 TWh/yr or more of electrical energy storage in the future?

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