May 16, 2019

Maths, Physics & Chemistry

# Compressed air energy storage: a technology that (porous) rocks!

by Julien Mouli-Castillo[1] | Postdoctoral Research Assistant

[1]: The University of Edinburgh, Edinburgh, Scotland, United Kingdom

This Break was edited by Max Caine, *Editor-in-chief* - TheScienceBreaker

ABSTRACT

*When most electricity will be generated from variable renewable energy sources storing large amounts of it from summer to winter will be required. We find that the compression of air within porous rocks below ground could meet that storage need.*

*Image credits: Pixabay – CC0*

Climate Change is caused, in parts, by the increase in greenhouse gas emissions, such as carbon dioxide, to the atmosphere. One of the main sources of carbon dioxide is power plants. Hence, more and more renewable energy sources, commonly known as "renewables", such as wind, tidal, or solar, are used to generate electricity. Renewables are naturally variable and can't be controlled. We, therefore, need to be able to store electricity that is produced but not needed. We can then use it at a later time when we will need it but the wind will not be blowing. Many storage options exist for hourly to daily storage, for example, hydroelectric plants which use excess electric power to pump water up a hill and can let it down again later to produce electricity.

However, when over 80 % of our electricity will come from renewables we will need to store electricity from the summer to the winter. Currently, no commercially mature technology is able to achieve this seasonal storage. We studied a potential candidate: Compressed Air Energy Storage (CAES). This technology is commercially mature. It consists of using excess electricity to compress air in caverns mined from salt 700 m underground via a well. The compressed air is stored for a few hours and then released back to the surface where it is used in a gas turbine to generate electricity. The caverns are too small to allow enough air to be stored for seasonal storage. We investigated the possibility of using porous rocks instead. These rocks formed over millions of years from compacted beaches and deserts and can span hundreds of kilometers squared and be hundreds of meters thick. We used computer models to estimate how much air could be safely stored in those rocks, and how much electricity could be generated from it. We then used a streamlined mathematical representation of those models to estimate how much electricity could be produced by the compressed air in winter for the UK.

It is very difficult to know exactly how porous rocks hundreds of meters below the ground look. To work around this lack of data we opted for an approach which involved building a conceptual model of the porous rock store and varying its properties over ranges recommended by a large body of research. Those ranges ensure that the storage operation is both safe and allows the air to be injected and recovered from the rock fast enough. We also built a model to account for pressure changes between the store and the surface. Finally, we built models for the gas turbine and air compressor which we verified using data from the two operating CAES plants worldwide. We then varied the compressor and turbine parameters to obtain a realistic coverage of various designs and operating conditions. Overall, 736 simulations were done, each providing a power output for a specific compressor, turbine, well, and porous rock store parameters. We then used a method called "multiple variable regression" to relate the porous rock store depth, and the turbine parameters, to the power output, in what is called a "predictive model". Using a database of the offshore UK geology we obtained the depth of offshore porous rock formations, from it we could calculate the expected compressed air density, and using our predictive model the expected power output, and therefore the amount of electricity which could be produced over two winter months.

The results showed that the amount of produced electricity over two winter months would be enough to power the whole of the UK and more (143 to 180 % of the UK's electricity demand in fact). This encouraging result comes with some limitations. Achieving all that electricity production potential would require an investment in infrastructure equivalent to that of the offshore oil and gas industry in the UK over the past 40 years. In addition, the cost of offshore CAES used for seasonal storage is still uncertain, and currently more expensive than daily onshore CAES. Further research could help reduce costs and uncertainties. More work is needed to understand the chemical reactions that might be caused by injecting air deep into the porous rocks. We still do not know how much seasonal storage of electricity will be needed. Research answering this would help put the results from this study in perspective.

In conclusion, this study has shown that an existing commercially viable technology could provide a vast amount of electricity storage potential and that research is required to put this finding in the context of our future seasonal electricity storage need.