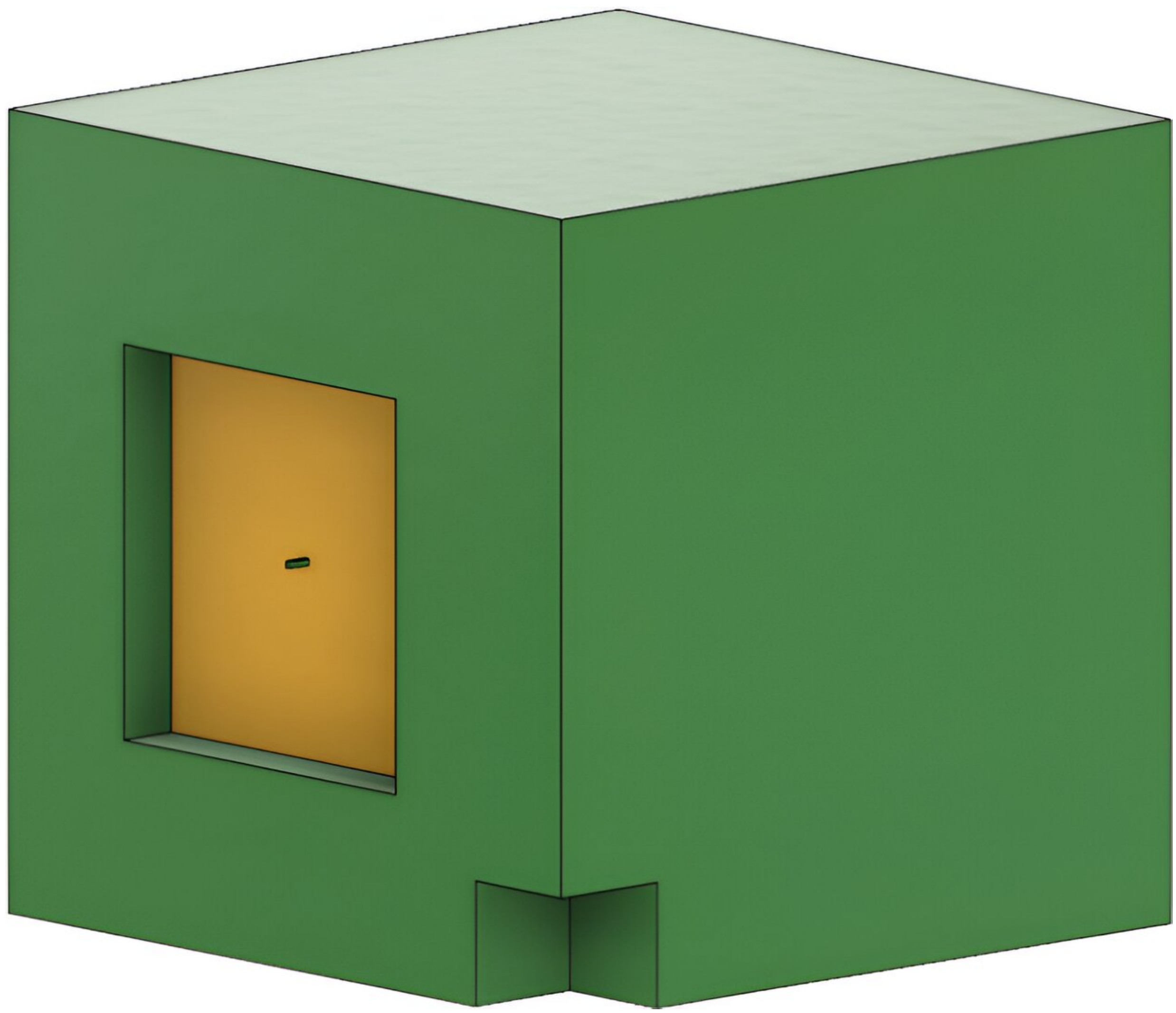
Compressed air energy storage systems could replace conventional batteries as energy providers, say scientists

February 5 2024, by University of Sharjah



To-scale comparison of battery output (rectangular dent at the bottom of the cube) compared to the equivalent volume of air storage required. The yellow area indicates a ~160 kW of 500 solar panels of 1×2 m^2 dimensions compared with an equivalent ~210 hp four cylinder internal combustion engine, also to scale. Credit: *Journal of Energy Storage* (2022). DOI: 10.1016/j.est.2022.105263

A group of scientists have found compressed air energy storage systems to have the potential of replacing conventional electrochemical batteries as a cheaper alternative, and with better storage capacity that is even sufficient to keep AC gadgets running.

The team led by University of Sharjah's Professor of Sustainable and Renewable Energy Abdul Hai Alami have published the results of their research titled "Performance assessment of buoyancy work energy storage system with various buoy materials, coatings, and gasses" in *Journal of Energy Storage*.

The paper, according to the authors, expands and draws on an earlier 2022 publication titled "Experimental evaluation of compressed air energy storage as a potential replacement of electrochemical batteries" published in the same journal.

The researchers work comes under the appellation "buoyancy work energy storage" which depends on applying a force through pulleys and ropes on a floating buoy to descend it below the water surface during periods of high energy production. Once the buoy reaches its maximum allowed depth, it is locked in place using an anchor.

When energy is to be harvested back, the buoy is allowed to ascend to the surface of the water body, rotating an electrical generator in the process, which facilitates the transformation of the stored potential energy into useful electrical energy.

Prof. Alami notes, "Overall, a levelized cost of electricity to a system of this nature that would be coupled to an offshore wind turbine array (i.e., the London array) is expected to be 0.978 cents($)/kWh, which is considered to be competitive to other technologies, such as batteries, standing at 8.69 cent($)/kWh, for the same conditions.

"Since the idea is based on a basic physical principle that appeals to many scientists, its implementation potential is understandable and straightforward and brings the industry one step closer to replacing the total dependence on batteries in energy generation."

Prof. Alami says he and his co-authors now have a project that "truly showcases the potential of replacing conventional electrochemical energy storage, by a cheaper alternative, all while having an AC output, which is desirable for most domestic appliances."

Prof. Alami hopes that the project and the two articles he and his colleagues have published will raise awareness that batteries are not the sole method of energy storage despite the current bias towards electrochemical batteries which is seen by many "as the go-to storage technology [and] the first answer one would think of when asked about energy storage devices."

In their first study, the authors show novelty in terms of testing compressed air energy storage systems against conventional electrochemical batteries and provide ground for comparison with proper quantification coupled with mathematical evidence that compressed energy storage can replace conventional electrochemical batteries.

The setup of the experiment conducted by the scientists consists of air tanks, turbo expanders (air motors), gearboxes and an AC permanent magnet generator. "These equipment[s] provided an experimental roundtrip efficiency of around 60% equipment with more room for future enhancements," the scientists note in their study.

Says Prof. Alami, "For example, the research has concluded that at an operating pressure of 10–12 bar, and a storage pressure of 80–100 bar, an operation carried out by a 12 V battery is equivalent to storing 12 m^3 of air in the aforementioned conditions.

"Moreover, in terms of economy of scale, a levelized cost of electricity for the compressed air energy storage system of 8.09$/kWh/kW was achieved, compared to that for a 1400 kWh lead acid battery of 44.6$/kWh/kW."

The authors say their work holds promises for the future and write that their experimental evaluation "is expected to pave the way for further experiments and innovation in specialized air handling turbines for large-scale energy storage."

They write, "In any case, the adaptation of the compressed air energy storage system is viable and would require sincere adaptation of a new storage mix paradigm, especially in the provision of appropriate storage tanks and their pertinent space required. This space will mainly be underground, akin to underground tanks in gas stations, and not much larger in volume."

Meanwhile, they add that compressed air energy storage is a viable and scalable energy storage technology that can be used on- or off-grid, exhibiting "a strong potential for replacing electrochemical batteries for grid-scale energy storage.

"This work has highlighted [and] experimentally assessed the technical feasibility of using a compressed air energy storage system to replace a conventional battery system," they write.

The findings of their research, particularly in their earlier study, have already garnered considerable interest from the industry, the authors claim. They say some leading international companies and startups have already approached them for the possibility of industrial scale application.

Besides some leading companies in the United Arab Emirates (UA), where the research is conducted, Prof. Alami mentions a few "international companies and startups, such as TerraStor (terrastor.co) in Texas, U.S., (who) are in touch with the team on a regular basis for discussions on latest technologies."

The interest in the project is expected to grow because, according to Prof. Alami, his team have obtained "definite and a solid proof that compressed air energy storage has the potential to become a strong competitor in the energy storage scene to pre-established energy storage technologies, like electrochemical batteries."

The authors make reference in their study to plenty of practical implications, which include, among other things, energy storage, cooling applications, as well as enhancing the round-trip efficiency and decreasing the cost of energy systems. Since compressed air energy storage systems are scalable, then they can be implemented for a wide spectrum of applications, the authors maintain

The authors do not deny the utility of electrochemical options which can provide high energy density with low maintenance requirements. However, they note that "their production costs and fast degradation constrain their widespread use in grid-scale applications … considering other types of energy."

The authors map the current energy storage scene. For instance, they point to fuel cells and flow batteries which "can mitigate the low energy density of batteries when compared to fossil fuels such as petrol … However, these fuel cells are expensive to install, and the production of hydrogen requires substantial amounts of energy, thus reducing its usefulness in many applications."

They find that the "The integration of energy storage systems with other types of energy generation resources, allows electricity to be conserved and used later, improving the efficiency of energy exchange with the grid and mitigating greenhouse gas emissions.

"Moreover, storage provisions aid power plants function at a smaller base load even at high demand periods thus, initial investment and electricity generation costs will significantly decrease."

The main thrust of the project is to provide evidence that batteries are not the only available option for energy storage, especially on the large-scale.

"Our research illustrates that compressed air energy storage is a viable alternative to batteries, especially when underground caverns are available for large-scale energy storage," said Prof. Alami.

More information: Abdul Hai Alami et al, Performance assessment of buoyancy work energy storage system with various buoy materials, coatings, and gasses, *Journal of Energy Storage* (2023). DOI: 10.1016/j.est.2023.108524

Abdul Hai Alami et al, Experimental evaluation of compressed air energy storage as a potential replacement of electrochemical batteries, *Journal of Energy Storage* (2022). DOI: 10.1016/j.est.2022.105263

Provided by University of Sharjah