# Analysis and Comparison of the Application Prospects of Energy Storage Technologies in Guangdong Province, China

Yuanxi Li
*Shenzhen Nanshan Foreign Language School, Shenzhen, Guangdong province, 518000, China*

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Abstract: After the Industrial Revolution, people began to pursue energy vigorously. However, with the continuous increase of energy demand, traditional fossil energy will not be able to meet the needs of society. To this end, emerging renewable energy technologies were born. However, with the continuous of renewable energy technology progress, there is an imbalance between energy supply and demand. As a result, many energy storage technologies have been invented to conserve energy for use in times of high demand. However, various regions are characterized by distinct environmental conditions, encompassing climate, physical geography, and diverse social needs. As a result, energy storage technologies tailored to local conditions are essential for effectively meeting the energy requirements of the respective communities. Finding the appropriate storage technology for each location will enhance people's quality of life and promote more efficient energy usage. Guangdong, an economically and demographically important province in China, has huge energy demands. In this paper, the application prospect of three kinds of energy storage technology including air compression energy storage technology, pumped-storage hydroelectricity technology and rechargeable battery in Guangdong region is investigated. By means of data comparison and factor analysis, the influence of Guangdong's special environmental conditions on different energy storage technologies and their applicability are analysed. It is concluded that seawater pumped storage is the most suitable technology for Guangdong Province, which can not only ensure the minimum impact of the conditions, but also make full use of the superior resources in Guangdong.



## 1 INTRODUCTION

In the last few decades, society's demand for energy has increased since the global level of industrialization and urbanization is faster and faster. Due to population growth, global energy demand is expected to increase sharply (Bazdar et al., 2022). In order to adapt the increased demand, fossil fuels have been adopted on a massive scale. However, the use of these fuels has led to a number of environmental problems. Such as over-exploitation of land resources, oil spill pollution and global warming. In recent years, in order to mitigate the environmental impact of coal and oil and satisfy the growing energy demands of urban areas, the attention to the large-scale use of renewable energy sources has increased considerably. However, the limitation of renewable energy sources lies in the fact that their supply does not always align with people's demand. This lack of uniformity in timing presents a challenge for meeting energy needs efficiently. Some emerging energy storage technologies solve this problem. Therefore, in this paper, the application prospects of different energy storage technologies in special areas, such as Guangdong, are focused on. As a first-tier province in China, Guangdong has an area of 179,800 square kilometers and a permanent population of 115.21 million, which has a very large energy demand. In 2019, Guangdong's total energy consumption was 341 million tons of standard coal (Zhang and Chen, 2019). Therefore, Guangdong urgently needs to carry out transformation of green resources and adopt new energy storage technology. At the same time, due to the complex climate conditions, geographical conditions and economic effects in Guangdong, it is necessary to the overall analysis of the energy storage technology, different application scenarios and their features, and find the most suitable one. In this paper, three technologies used as energy storage solution in the world are analyzed. The potential applications of energy generation technologies explored in the Guangdong region are by conducting a comparative



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analysis of data from similar regions around the world. Additionally, it will provide recommendations for selecting appropriate energy generation technology in the Guangdong region.

# 2 COMPRESSED AIR ENERGY STORAGE (CAES) TECHNOLOGY

## 2.1 Operating Principle

CAES technology storages energy by compressed air, and it has the advantages of long duration and low cost. During high supply/low demand cycles, the CAES system converts solar or wind energy into electricity for compressing air. The air will be stored in special storage units, such as above-ground storage tanks or underground caverns. During low supply/high demand cycles, this compressed air will be released and expanded through an expander. Then electricity is generated by driving turbines, converting their internal energy into electricity for people to use. CAES technology has been very mature, now there are Diabetic-Compressed Air Energy Storage (D-CAES), Adiabatic-Compressed Air Storage (A-CAES), Advanced Adiabatic-Compressed (AA-CAES) technology and so on. This paper mainly discusses AA-CAES technology.

## 2.2 Performance Analysis

### 2.2.1 Energy Efficiency

Thermal energy storage (TES) technology makes up for the low energy efficiency of traditional CAES technology. The energy conversion rate of the AA-CAES system after adding TES technology, can generally reach 65%-70%. In an experiment, it was determined that the energy conversion rate of AA-CAES technology could reach 63-74%, higher than the predicted 60%-65% (Geissbühler et al., 2018).

### 2.2.2 Energy Density

The energy storage density of CAES technology is often in a low level, generally at the range of 3-6Wh/L (He and Wang, 2018). The factor that most affects this indicator is the choice of energy storage materials in the system. CAES technology uses air as energy storage material, which is not an efficient material. That means that CAES technology is more promising in larger projects.

### 2.2.3 Energy Storage Duration

The biggest advantage of AA-CAES technology is its long duration. It is predicted to last longer than 30 years. In fact, the AA-CAES technology that has been put into use can generally be maintained for 20-30 years in the absence of other factors (economics, policy, corporate decisions, etc.) (King et al, 2021). Due to its low energy density, CAES technology experiences minimal energy loss over an extended storage period, making it a highly efficient option for long-term energy storage.

## 2.3 Feasibility Analysis

AA-CAES technology takes high energy conversion efficiency and long storage duration as merits. At the same time, it also needs to meet some conditions. First of all, the high energy conversion rate of AA-CAES largely depends on the application of advanced TES systems. Some studies have shown that TES system will be affected by external temperature (DeForest et al., 2014). Singapore is a tropical rainforest climate zone and Guangdong belongs to the subtropical monsoon climate zone. Both climates have the characteristics of high temperature and high annual rainfall. Therefore, this paper compares the impact of TES system in Singapore with that in Guangdong. A study conducted in Singapore showed that TES systems are affected by temperature changes throughout the day. It is affected by Partial load operation, Peak-load management and Price arbitrage, and the extent of the impact is widespread. The study also suggests ways to deal with it. However, the conclusion is that the TES system is not suitable for use in places with high population density, because it requires a larger space for heat conversion (Comodi et al., 2016). Besides, AA - CAES system energy density at a low level. Therefore, the use of AA-CAES technology as a large-scale energy storage system requires large-capacity containers, such as large and stable underground caverns or large-scale above-ground storage tanks (Geissbühler et al., 2018). Guangdong is in the monsoon climate area, and many typhoons often on land in summer, accompanied by continuous heavy rain. Heavy rains eroded the land surface, causing landslides. Therefore, it is difficultly that building the large-scale underground caves artificially in Guangdong has good stability. On the other hand, building large-scale storage tanks on the surface seems more feasible. Although the population

density of Guangdong is at a relatively high level, some areas in the periphery still have a large amount of available place. However, the resistance of the above ground storage tank to typhoon remains to be studied. The CAES storage tanks in Singapore are not severely affected by typhoons, but this is most likely because Singapore is not particularly affected by typhoons. Therefore, whether the above ground storage tank can be used in Guangdong area is still to be studied and discussed.

# 3 PUMPED-STORAGE HYDROELECTRICITY (PSHS)TECHNOLOGY

## 3.1 Operating Principle

Pumped storage uses water as storage medium and achieves energy storage destination through the mutual conversion of potential energy and electric energy. At high supply/low demand cycles, pumped storage systems run pumps with low-cost electricity to transfer water from the lower reservoir to the upper one, increasing the potential energy of the water. During the opposite cycles, the water stored up drives hydraulic turbines, which generate electricity. Pumped storage technology is the most economical technology with long storage period, stable high energy conversion rate and large capacity form. Typical pumped hydroelectric energy storage (W-PHES) plants include wind pumped hydroelectric energy storage (W-PHES) plants, solar photovoltaic pumped hydroelectric energy storage (PV-PHES) plants, and seawater pumped hydroelectric storage power plants (Rehman et al., 2015).

## 3.2 Performance Analysis

### 3.2.1 Energy Efficiency

Pumped storage technology has a high energy conversion rate. Its ability conversion rate can generally reach 70%-80% in different situations, and some people claim that it can reach 87% (Kong et al., 2017). Efficient energy conversion results in less energy loss and lower cost, which is more significant in large-scale storage, which also makes pumped storage technology widely used around the world.

### 3.2.2 Energy Density

PHES technology has a lower energy density. The siting of the PHES system should have at least a large body of water or a drastic height change (Comodi et al., 2016). Therefore, the location of PHES system is very important. The former compensates for the low energy density with capacity, while the latter compensates with the average potential energy.

## 3.3 Feasibility Analysis

Wind energy is one of the earliest clean energy sources used by humans, and W-PHES technology is now being used all over the world. The technology is well established and is typically used in Turkey and the Mediterranean region, which are usually built on islands to provide energy for more isolated islands that are difficult to transport (Petrakopoulou, Robinson and Loizidou, 2016). This is the application of small and medium-sized wind energy storage technology. Guangdong Province is in the subtropical monsoon climate zone and has abundant wind resources. At the same time, Guangdong Province is a coastal province with many small islands (such as Chuanshan Islands, Wanshan Islands, etc.). Guangdong's environmental conditions seem to be ideal for the construction of wind pumped storage power stations. But there are potential problems. Typical wind-pumped storage plants, such as those in the Mediterranean, rely on islands and supply only islands. Whether such a power station can supply enough energy to the Guangdong region is a question that requires precise calculation and reasoning.

PV-PHES technology is a PHES technology with solar energy as the main application energy. The regular indirect nature of solar energy, it can only be collected during the day (Hammad et al., 2024). Guangdong, located in the subtropical region, has abundant light resources, but these resources are not evenly distributed throughout the year, and the polarization is more serious. From July to October, Guangdong can maintain good light duration and light intensity. But in November to January, that is, winter, Guangdong is mostly cloudy. From February to June, that is, spring and early summer, Guangdong is affected by the southeast monsoon, the weather is changeable, accompanied by heavy rain and typhoons. In other words, it was difficult for Guangdong to maintain a stable supply of daylight in the first half of the year, while sufficient solar energy was concentrated in July-October. Therefore, PV-

PHES technology can be applied in Guangdong, but whether it can be stable for energy supply is still to be discussed.

Seawater pumped hydroelectric plants is the most suitable for the application among these three technologies in Guangdong. First of all, Guangdong Province is located in the seaside, there are rich sea water resources and island resources. As early as 2017, China's National Energy Administration carried out a survey of the resources of seawater pumped storage power plants in coastal provinces. According to the report, Guangdong has 57 resource sites with a total resource of 11.46 million kilowatts, accounting for 27.2 percent of the country's total resources (National Energy Administration of China, 2024). On this basis, the energy Bureau further screened these sites and eventually selected eight sites with relatively good conditions across the country, three of which were in Guangdong Province. In addition, small seawater technology is an advanced and mature technology in the world and can be directly applied to a small-scale pilot. There is only one precedent for large-scale seawater technology, a seawater pumped storage power plant on the Japanese island. If Guangdong Province can adopt this technology, it can make use of the good resources and contribute to the world's technological practice.

# 4 ELECTROCHEMICAL ENERGY STORAGE

## 4.1 Operating Principle

Electrochemical energy storage system uses chemical energy storage battery as a medium for energy storage. The technology converts clean energy into chemical energy when demand is low and stores it in batteries. At peak times, the battery converts chemical energy into electricity, releasing previously stored energy. Compared with other technologies, electrochemical storage technology has larger energy per weight and transforms energy faster. At present, in the application of materials, rechargeable batteries can be divided into several categories (Tian, Zhan and Yan, 2021). Overall consideration, the lithium-ion battery has the merits of high energy density and environmental friendliness.

## 4.2 Performance Analysis

### 4.2.1 Energy Density

A characteristic of lithium-ion batteries is their high energy density. As early as the early 21st century, lithium-ion batteries can reach an energy density of 200-400 Wh/L (Chen et al., 2020). High energy density means the need for smaller volumes, which is in line with the demand for energy storage technology in cities with limited land, such as Guangdong.

### 4.2.2 Energy Efficiency

Lithium-ion batteries have the highest energy density among the three technologies mentioned in this article, reaching about 90%, and can even reach 97% under suitable conditions (Yu, Wang and Chan, 2020). The utilization rate of energy is a vital noble to judge whether an energy storage system is available.

### 4.2.3 Duration

Lithium-ion battery has a disadvantage in energy duration. The positive and negative electrodes of lithium-ion batteries will suffer some irreversible damage. At present, the irreversible capacity loss of the most widely used graphite negative electrode is greater than 6%, and for the silicon and tin alloy negative electrode with a high specific capacity, the irreversible capacity loss is even as high as 10% to 20% (Thompson et al., 2020). In recent years, some lithium replenishment technologies have been studied to eliminate this drawback of lithium-ion batteries. However, these techniques only have experimental data and have not been applied in practice.

## 4.3 Feasibility

The advantages and disadvantages of lithium-ion batteries are obvious. On the bright side, first of all, it has an energy conversion rate that exceeds most energy storage technologies, which is in line with people's needs for energy storage technology. In addition, its high energy density makes it also very suitable for use in Guangdong, which has a high degree of population density. These two indicators are important criteria for people to choose technology. However, the drawbacks of lithium-ion energy storage technology are also obvious. First, batteries have been used in small devices in recent years (Meister et al., 2016). For example, new energy vehicles or energy storage devices for small-scale applications. There are not many examples of large-

scale devices being used worldwide. Secondly, the consumption of lithium batteries is still to be solved. In small devices, perhaps this problem is not obvious, but if you want to supply power to a large area of Guangdong, the consumption of lithium batteries will be a problem that must be solved. Finally, some questions have been raised about whether lithium-ion batteries are really environmentally friendly devices. Due to the rapid development of technology, the composition of lithium batteries is extremely variable and complex. In contrast, the technology for treating exhaust lithium-ion batteries does not identify and separate these different materials well, often leading to incomplete recycling and pollution of the external environment (Mrozik et al., 2021). If lithium-ion batteries will be put into use in Guangdong, this paper believes that these problems are urgent to be solved.

# 5 CONCLUSION

This paper finds that various energy storage technologies have different degrees of application in Guangdong. AA-CAES technology has lower cost and higher energy conversion rate, but the high energy conversion rate of AA-CAES technology depends on its advanced TES system. However, the climate and complex weather conditions in Guangdong Province are not suitable for large-scale use of TES system. In addition, Guangdong Province does not have the stability and sufficient space required for AA-CAES systems. Rechargeable battery technology has a high energy conversion rate and high energy density, this means that it can occupy a smaller space and store more energy. There are still many technical issues to be resolved. Pumped storage system has good conditions in Guangdong. Although the W-PHES technology and PV-PHES technology have the problem of discontinuous energy supply, the seawater pumped storage system can avoid these problems. There's plenty of research to prove it. To sum up, this paper considers that seawater pumped storage technology is the most suitable technology to be used in Guangdong. Application possibility of different energy storage technologies and the possible impact of climate and geographical conditions in Guangdong Province are analyzed in this paper. Some suggestions for selecting energy storage technologies suitable for Guangdong Province are provided. The analysis in this paper is the integration and analysis of various energy storage technologies and the overall situation of Guangdong Province. We can further study and analysis the data differences and influencing factors in the actual application of various technologies in Guangdong Province, and conduct quantitative analysis.

# REFERENCES


Bazdar, E., Sameti, M., Nasiri, F., et al. 2022 Compressed air energy storage in integrated energy systems: A review *Renewable and Sustainable Energy Reviews* **167** 112701

Zhang, J., & Chen, Y. 2019 Risk assessment of flood disaster induced by typhoon rainstorms in Guangdong province, China *Sustainability* **11** 2738.

Geissbühler, L., Becattini, V., Zanganeh, G., et al. 2018 Pilot-scale demonstration of advanced adiabatic compressed air energy storage, Part 1: Plant description and tests with sensible thermal-energy storage *Journal of Energy Storage* **17** 129-139

He, W., & Wang, J. 2018 Optimal selection of air expansion machine in Compressed Air Energy Storage: A review *Renewable and Sustainable Energy Reviews* **87** 77-95

King, M., Jain, A., Bhakar, R., et al. 2021 Overview of current compressed air energy storage projects and analysis of the potential underground storage capacity in India and the UK *Renewable and Sustainable Energy Reviews* **139** 110705

DeForest, N., Mendes, G., Stadler, M., et al. 2014 Optimal deployment of thermal energy storage under diverse economic and climate conditions *Applied energy* **119** 488-496

Comodi, G., Carducci, F., Nagarajan, B., et al. 2016 Application of cold thermal energy storage (CTES) for building demand management in hot climates *Applied thermal engineering* **103** 1186-1195

Rehman, S., Al-Hadhrami, L. M., et al. 2015 Pumped hydro energy storage system: A technological review *Renewable and Sustainable Energy Reviews* **44** 586-598

Kong, Y., Kong, Z., Liu, Z., et al. 2017 Pumped storage power stations in China: The past, the present, and the future *Renewable and Sustainable Energy Reviews* **71** 720-731

Petrakopoulou, F., Robinson, A., & Loizidou, M. 2016 Simulation and analysis of a stand-alone solar-wind and pumped-storage hydropower plant *Energy* **96** 676-683

Hammad, B., Al-Dahidi, S., Aldahouk, Y., et al. 2024 Technical, Economic, and Environmental Investigation of Pumped Hydroelectric Energy Storage Integrated with Photovoltaic Systems in Jordan Sustainability **16** 1357

National Energy Administration of China. Results of resource survey of seawater pumped storage power station. Retrieved on June 12 2024, retrieved from https://www.gov.cn/xinwen/2017-04/07/content_5183621.htm

Mengyu, Tian., Yuanjie, Zhan, & Yong, Yan. 2021 Replenishment technology of the lithium-ion battery *Energy Storage Science and Technology* **10** 800

Chen, T., Jin, Y., Lv, H., et al. 2020 Applications of lithium-ion batteries in grid-scale energy storage systems *Transactions of Tianjin University* **26** 208-217

Yu, W., Wang, T., & Chan, Y. 2020 Influence factors of charge-discharge energy efficiency of Li-ion battery for energy storage *Battery Bimonthly* **50** 552-555

Thompson, D. L., Hartley, J. M., Lambert, S. M., et al. 2020 The importance of design in lithium-ion battery recycling-a critical review *Green Chemistry* **22** 7585-7603

Meister, P., Jia, H., Li, J., et al. 2016 Best practice: performance and cost evaluation of lithium-ion battery active materials with special emphasis on energy efficiency *Chemistry of Materials* 28 7203-7217

Mrozik, W., Rajaeifar, M. A., Heidrich, O., et al. 2021 Environmental impacts, pollution sources and pathways of spent lithium-ion batteries Energy & Environmental Science **14** 6099-6121