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Characteristics of electrical energy storage technologies and their applications in buildings

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ABSTRACT

This study has been undertaken to gain a better understanding of how to allow for energy storage in the design of a future built environment where renewable energy systems will play a significant role.

Electricity storage solutions are a key element in achieving high renewable energy penetration in the built environment. This paper presents an overview of electricity storage technologies and their distinct characteristics. The currently available technologies have been classified according to the means by which each can be used in supplying energy to buildings.

As the storage market is evolving rapidly, the analysis provides an up-to-date evaluation of different storage options with regard to scale, reliability and site-specificity among others.

It is concluded that Li-ion batteries, which today have a limited use in the built environment, and Zn–air batteries that will be commercialised in 2013/14 are amongst the most promising technologies for buildings due to their exceptionally high energy density. They are expected to play an important role in reliable, economical and energy efficient building design in the future. NaNiCl batteries, which are currently used in vehicles, are also considered an important technology for buildings, because of their high cycle lifetime and their high peak power capability.

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1. Introduction

In the last decade, increased environmental concerns have led to the formation of European energy and climate policies, which suggest a significant CO_2 emissions reduction for the EU countries by up to 95% by 2050 is needed [1]. Towards this goal, the integration of renewable energy sources in the energy mix of the future is expected to rise (Fig. 1). However, the output of many renewable energy sources, such as wind and solar, is highly variable, producing fluctuating and partly unpredictable amounts of electricity over time [2–5]. Therefore, the constant mismatch between supply and demand can have a serious impact on grid reliability and security of supply. This constitutes a new challenge, which requires the introduction of advanced energy storage solutions.

There are a number of benefits associated with the introduction of energy storage systems in the built environment. Electrical energy storage (EES) systems can contribute to increasing power systems' efficiency, as they can effectively manage the surplus electricity generation from renewable energy technologies, which would otherwise be wasted. In this way, electricity storage helps to maximise the value and the contribution of intermittent renewables [2,6]. Furthermore, EES systems can assist in the improvement of the electrical grid stability and reliability, as they can address the fluctuations in consumption and generation by providing the necessary flexibility [2]. In addition, EES solutions can contribute to the increase of energy security and quality of supply, by sustaining frequency and voltage at the required levels [2,7]. For example, electricity storage options could deal with the occurring voltage sags in case of a power failure, ensuring reliability of supply.

This paper focuses on the use of EES systems in buildings, which account for a significant share of global electricity end use and carbon emissions. Therefore, the built environment with its various uses has a high emission reduction potential and this could be achieved through a modern electricity supply system based on renewable sources and their smart management. EES systems will provide operational flexibility within a building or in the electric grid, by injecting and absorbing electrical energy to and from the grid as needed. Hence, a combination of EES systems in a variety of sizes and scales, from bulk EES installations to smaller community and local EES systems, will eventually emerge in the future built environment [8].

According to [9], there is a great potential for environmental, economic and energy diversity benefits through the use of advanced electricity storage technologies. Considering the planned large-scale introduction of renewable energy sources in the built environment in the coming years, electricity storage will play a double role. On one hand, it will enable renewable energy to be captured and stored for later use, without wasting extra amounts of resources for electricity generation; therefore, according to [9], it will be a source of efficiency. On the other hand, it can also serve as a valuable tool that will provide the needed flexibility in energy supply, by smoothing out the mismatch between supply and demand. Given the attempts currently being made towards the reduction of CO_2 emissions, electrical energy storage technologies, along with renewable energy technologies, are expected to be a necessary element of the built environment in the future [5,6,9–13].

With growing concerns about the environmental impacts of the electricity sector, the EES market is developing quite rapidly and the performance characteristics of the technologies are constantly improving. Furthermore, there are a limited number of inter-institutional collaborations in this field globally at present. Some collaborative research projects have been taking place in the US with good results [12,15–20]. However, a great deal of research on EES around the globe is conducted by Universities, organisations or companies independently. Hence, the aim of this study is to gather the most recent findings in the field and analyse their potential use in relation to the integration of EES systems in the built environment.

The EES technologies considered in this review are the following:

1. Superconducting magnetic energy storage (SMES),
2. Supercapacitors/electrochemical double layer capacitors (EDLCs),
3. Pumped hydroelectric storage (PHS),
4. Flywheels,
5. Compressed air energy storage (CAES),

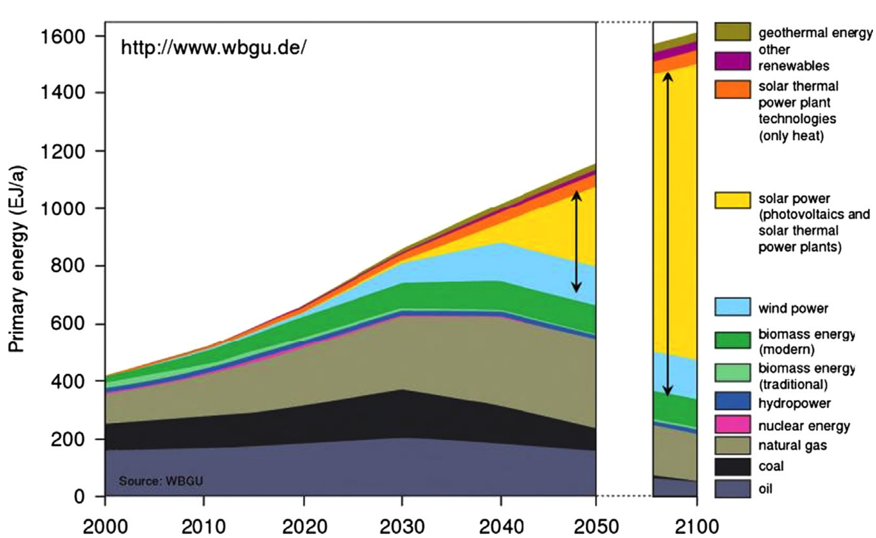

Fig. 1. Scenario for a worldwide energy mix in the next decades [11,14] (after the German Advisory Council on Global Change 2008).