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Lithium in thermal energy storage: A state-of-the-art review

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ABSTRACT

Lithium, mainly used in electrical energy storage, has also been studied in thermal energy storage. It is recognized as a "critical material" and is produced from minerals and from brines. Chile is one of the biggest producers, here from brine and with lower costs than in other countries. With sensible heat storage, in solar power plants lithium is seen as a way to improve the properties of molten salts used today. The low melting point in these ternary salts with lithium, represent a considerable reduction in the maintenance and operational costs associated with current solar technology, demonstrating that the fluids showed, are potential candidates for thermal energy storage (TES) in concentrated solar plants (CSP) plants. Many materials have been studied and proposed to be used as phase change materials (PCM). Between the multiple materials studied to be used in PCM, lithium materials and mixtures are listed as potential PCM for building applications and for high temperature applications. In thermochemical energy storage, lithium compounds have been used mainly in chemical heat pumps, following their use in absorption cooling.

Contents

1. Introduction

Thermal energy storage (TES) is used to keep thermal energy to be used at a later time. A complete TES process involves at least three steps: charging, storing and discharging (Fig. 1) [1]. The most important part of the storing step is the storage media. A wide variety of choices exists, depending on the temperature range and the application. There are several types of TES methods, shown in Fig. 2. Basically one can use a physical process or a chemical process. Physical processes are sensible heat storage and latent heat storage. For sensible heat storage, water is a common choice because, among its other positive attributes, it has one of the highest specific heats of any liquid at ambient temperatures. Solids have the advantage of higher specific heat capacities, which allow for more compact storage units. TES using latent heat change can

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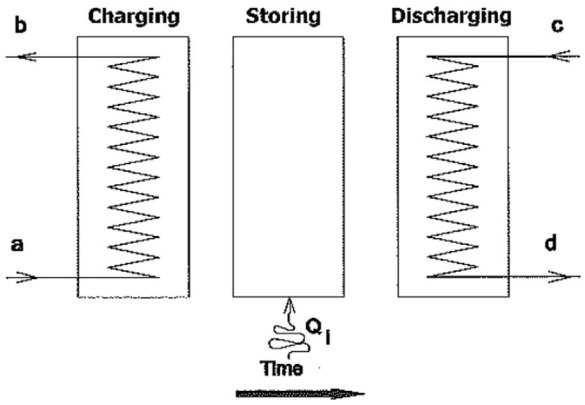

Fig. 1. Steps in a thermal energy storage process [1].

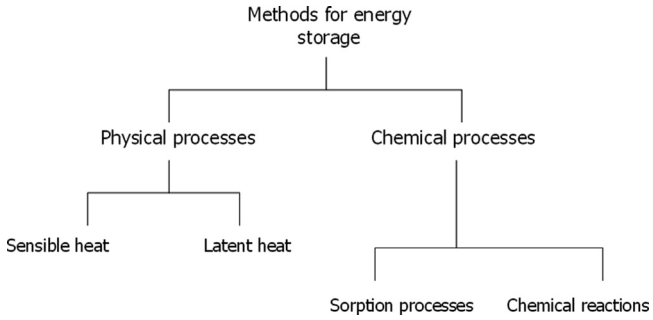

Fig. 2. Methods for thermal energy storage.

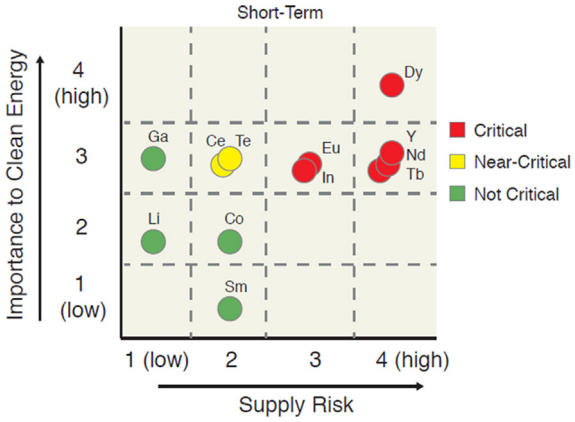

Fig. 3. Critical materials matrix [2].

also be used; the most common example of latent heat storage is the conversion of water to ice. The other category of storing heat it is considered through the use of reversible endothermic chemical reactions.

With the use of TES, systems achieve benefits by fulfilling one or more of the following purposes: increase the generation capacity, enable better operation of cogeneration plants, shift energy purchase to low cost periods, increase system reliability, or integrate other functions.

Lithium is recognized as a "critical material", that is, a material important to the clean energy economy and with risk of supply disruption [2] (Fig. 3). Materials are deemed important or have a high impact based on the particular properties that make them well suited for applications in which they are used. For photovoltaics, this might be the improvement of photovoltaic performance of electrochemical cells [3–5]; for magnetic materials it might be the magnetic flux density [6]; for thermal energy storage it might be the specific heat capacity [7–11] or the phase change

Table 1
Reserves and production of lithium in 2010 [15].

Key producers 2010	Annual production[a] 2010		Reserves	Reserves/ production
	Tons	%	Tons	
Country				
Chile	8,800	35	7,500,000	852
Australia	8,500	33	580,000	68
China	4,500	18	3,500,000	778
Others	3,500	14	1,420,000	406
World	25,300	–	13,000,000	514
Company	2009			
Global Advanced Metals	4,300	25	n/a	n/a
FMC Corp	2,400	14	n/a	n/a
Potash Corp of Saskatchewan Inc	2,010	12	n/a	n/a

n/a—not available.

[a] Pure lithium metal.

Table 2
Lithium demand by compound (merchant market)—Forecast 2011–2025 [14].

Compound—MT LCE	2011	2015	2020	2025
Lithium carbonate	68,445	95,068	149,43	253,739
Lithium hydroxide	25,824	49,889	99,297	183,303
Lithium concentrate	19,229	25,683	31,393	36,757
Lithium metal	7,755	9,763	13,193	18,256
Butil-lithium	7,293	9,445	13,232	18,617
Lithium chloride	7,616	9,516	12,782	16,922
Other lithium compounds	3,893	5,368	8,103	12,525
Total demand	140,056	204,732	327,743	540,119

enthalpy [12,13]. Lithium is always listed as a critical material in electric batteries [2,14]. Some of the materials are simply rare in their overall abundance in the earth's crust, or do not commonly occur in single deposits with significant concentrations; others are difficult to recover economically; others are byproducts of primary production of other materials.

Lithium is produced mainly in Canada, Brazil, Australia, some areas of Africa and Russia as mineral, and in China, USA, Argentina and Chile from brines. 61.8% of the total world lithium resources come from brines, around 26.9 Mt [14–16]. The abundance in Earth's crust is 19–21 ppm and in seawater 0.17–0.18 ppm [16]. The annual production in 2010 was 25,300 t; its distribution and the reserves by country are shown in Table 1 [15]. When lithium ore is exploited, its typical grade is 0.57–0.3%, with a minimum economic ore grade of 0.2–1% [16]. When comparing the productions costs of the lithium compounds from minerals and brines, countries producing lithium compounds from brines have lower production costs than those that produce them from minerals (2–3 $/kg vs. 6–8 $/kg) [17].

Lithium is mainly used in electrical energy storage, as the development of the electric car industry is based in lithium-ion batteries performance [15]. Lithium-ion batteries are also used for a wide range of electrical storage applications, from computers to video cameras. Lithium compounds are used in pharmaceuticals, as a mood stabilizer, and as an alloying agent to lighten and increase the strength of a number of metals, especially those used in the aerospace industry.

On the other hand, there are estimations of the lithium demand in the world, which give data on lithium demand by compound (Table 2) and by application (Table 3) [14]. It should be highlighted that meanwhile the demand of lithium compounds is expected to increase dramatically within the next few years, the application