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Climate crisis: energy storage challenges in the transition to renewable energies

Mariel A. Opazo

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Over the years, scientific research has advanced significantly and with this progress the importance of having an integral approach through interdisciplinary research has become apparent. This is most important nowadays when the conflicts that arise due to our climate crisis are multifaceted and have no evident solutions.

Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, Santiago, Chile. E-mail: mariel.opazo@uchile.cl

Mariel Opazo Damiani is a Chilean scientist living in Viña Del Mar, Chile. Mariel is a physicist from Universidad Técnica Federico Santa Maria, where she got her BSc and masters degrees. Her work relates to atmospheric chemistry and focuses on using chemistry-transport models to simulate atmospheric composition. She was a part of the group that created the first national inventory of anthropogenic emissions of Chile (INEMA) and is deeply passionate about making a difference through her research.

One way governments have decided to address the climate crisis is the 2030 Sustainable Development Agenda, which all countries in the United Nations adopted in 2015, with a commitment to 17 sustainable development goals (SDGs). The inequalities the SDGs aim to combat are only predicted to worsen with climate change, and therefore, one of them specifically targets the fight against it. Sustainable development necessitates a comprehensive approach that takes into account the connection between various goals while balancing social, economic, and environmental factors. Progress in one goal usually leads to improvements in the others, but that is not necessarily always true. Sufficient research needs to be conducted to obtain paths on how to tackle a specific goal without jeopardizing the progress of the others. Long strides, big political decisions and joint efforts need to be made to achieve them.

To combat climate change, one of the most important issues needing to be addressed is the reliance on fossil fuels for our energy consumption and transport needs.[1] As awareness of our climate crisis grows, more demand for renewable energy is created, and with that, innovations in technologies are needed to keep up with demand. One challenge that is faced in the process of adding renewable sources to the electrical grid is the need for large energy storage facilities to make sure energy is available when needed, given that the two most popular sources of renewable energy (solar plants and wind power) are intermittent. Furthermore, the increased demand for electrical means of transport has dramatically increased the need for batteries. It has become clear that energy storage is a crucial component for turning our world's grid electric, and with that comes a higher demand for the extraction of the earth's minerals, specifically lithium and rare-earth elements.[2]

Currently, lithium-ion batteries are used for around 90% of the grid energy storage around the world and clean technologies represent 30% of the total demand for lithium. The growing demand for solar power plants and particularly electric cars has led to a shortage of lithium that is predicted to get worse over time, despite the existence of large reserves. In fact, in a projected scenario consistent with climate goals, the expected supply is estimated to meet only 50% of lithium demand by 2030 and demand is anticipated to be 13 to 51 times higher by 2040.[2] Even though lithium is important for decarbonization, lithium extraction is particularly water intensive, which is made worse when considering that most of the lithium is found in drought-prone regions such as South America and Australia, both of which accounted for ~84% of global production in 2021.[1] Besides depleting water sources, lithium mining can cause ground destabilization and degradation, biodiversity loss, wildlife disruption, increased salinity of rivers, and contamination of soil, water and air.

As it stands, the shortage of lithium and energy storage capabilities presents a significant challenge for the development of renewable energies. Current methods for storing energy may not be scalable to meet future demand while also adhering to climate goals and protecting public health and the environment. Balancing these competing sustainability goals requires compromise and the exploration of new alternatives. It is in this aspect that the chemical sciences can play a pivotal role, as they can offer insights for future plans and aid in the creation of new technologies as solutions.

There are several research topics that address sustainable energy storage. These include enhancing the efficiency of lithium-ion batteries, developing non-lithium-based batteries, creating technologies that rely less on batteries, and studying new, more environmentally-friendly extraction methods. By focusing on these areas, researchers can contribute to the development of innovative energy storage solutions that are both sustainable and effective.

Improvements in efficiency, longevity and energy density are still ongoing for lithium-based batteries. Research suggests that progress can be made by using different materials and optimizing the architectures of the cathode and anode. It is also crucial to understand the chemical reactions that occur at the interfaces in the battery cell, as that could allow for enhanced performance by tailoring the design and electrolyte additives.[3]

There are several emerging technologies as possible replacements for lithium-ion batteries, such as sodium-ion, metal–air and solid-state batteries.[4] Sodium-ion batteries are attractive due to the abundance and low cost of sodium, but present challenges in the design given the ion's larger size. Metal–air batteries use metal electrodes and oxygen from the air as the cathode. These batteries have a high energy efficiency that is 5 to 30 times that of lithium-ion batteries.[4] Solid-state batteries offer improvements on issues like flammability and instability by using a solid electrolyte instead of lithium ions.

Aside from batteries, there are also other ways to store energy, such as pumped hydro-storage, compressed-air energy storage, or hydrogen storage, each of them with their own drawbacks. These methods involve storing energy in a different form and then converting it back into electricity when needed.

In order to mitigate the environmental impacts of lithium mining, it is critical to adopt responsible extraction practices. These practices include minimizing water usage, reducing air and water pollution, protecting soil quality, and preserving wildlife habitats. However, the best way to avoid the effects of lithium mining is by reducing demand for extraction. In addition to the above alternatives for energy storage and batteries, this can be accomplished by establishing a recycling system that can extract lithium from old devices and batteries.[5] Research suggests that improving technology efficiency or creating more environmentally friendly extraction methods is not enough, and what is most important is to change human behaviour to accommodate for current circumstances and the finite resources that exist on Earth.[5] For the case of sustainable energy storage and lithium batteries, these changes in behaviour can involve encouraging the use of public transportation and shared rides, as well as promoting recycling habits to reduce the need for lithium extraction. In addition to changing our behaviour, we must also invest in developing transportation options that do not require batteries.

By adopting a multifaceted approach that combines changes in human behaviour and technological advancements, we can move closer to a more sustainable and responsible energy future. A leading role falls to the chemical sector, not only as developments in the chemical and primary industries shape the whole supply chain, but also as innovations in current technologies lead to changes in reliance on problematic or inefficient systems. This will not only help to address the pressing environmental challenges we face, but also promote a more equitable and resilient society in line with the SDGs.

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