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A Color Code to Raise Public Awareness of Lithium Resources

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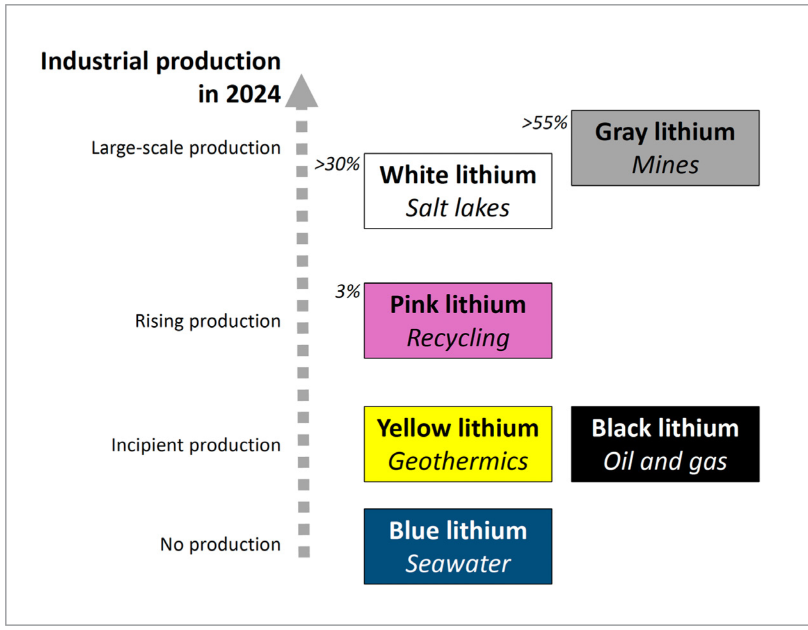

Figure 1. Proposed color code and associated nontechnical keywords (in italics) for the main types of lithium resources ranked by volume of industrial production in 2024 (arbitrary scale). Numbers in italics indicate the contribution to global production (after USGS, 2024; IEA, 2024).

INTRODUCTION

The global development of electric vehicles powered by lithium-ion batteries will put considerable pressure on raw material resources for decades to come (Maisel et al., 2023). However, the environmental impact of metal extraction seems to contradict the goal of the ecological transition, despite being considered one of its pillars (Sonter et al., 2023). In this context, it is crucial to raise public awareness and facilitate communication among stakeholders in the public debate (Brett et al., 2025). Color codes are already being used to refer to different water and hydrogen resources, as well as carbon sinks (Rost et al., 2008; Macreadie et al., 2021; Incer-Valverde et al., 2023). These color codes have various applications within the scientific community and serve as a practical tool for categorizing, communicating, and disseminating knowledge to the public. Here, we propose a simple color code for the main types of lithium resources to that end.

PRESENTATION AND USE OF THE COLOR CODE

The proposed color code is presented in a simple chart (Fig. 1) showing the main types of color-coded lithium resources ranked by volume of industrial production in 2024 and represented by colored boxes. The colored boxes indicate the lithium resources (e.g., white lithium), and nontechnical keywords describe their origin (e.g., salt lakes). As far as possible, the colors reflect the environment in which the resources are found. Combined with keywords, the colors serve as a simple mnemonic device that helps to capture the main characteristics and highlights the diversity of lithium resources. We also provide an overview of their geographic distribution in the form of a world map showing the location of emblematic lithium production sites and advanced projects, color-coded according to the proposed scheme (Fig. 2). The following paragraphs provide more details on the color-coded lithium resources and available estimates of their associated carbon and water use intensity. Using this color code, stakeholders in the public debate (citizens, scientists, companies, the media, policymakers, nongovernmental organizations, etc.) can share a simple common lexicon and basic knowledge without having to master all the technical vocabulary for discussing the issues of lithium extraction.

WHITE LITHIUM—SALT LAKES

White lithium is dissolved in the water beneath salt lakes, also referred to as “salars,” at concentrations of up to several thousand milligrams per liter. The term “white” refers to the color of the salt lake landscapes. However, white lithium is predominantly produced in three major areas: Argentina-Chile, China, and Nevada (Fig. 2). Processes that do not require lithium to be concentrated by solar evaporation over large surfaces will become widespread (e.g., “direct lithium extraction” [DLE]; Vera et al., 2023). However, extracting white lithium puts critical pressure on land use and water resources for populations living around salars, which are located in very arid climates. The production of one ton of lithium carbonate equivalent using the solar evaporation

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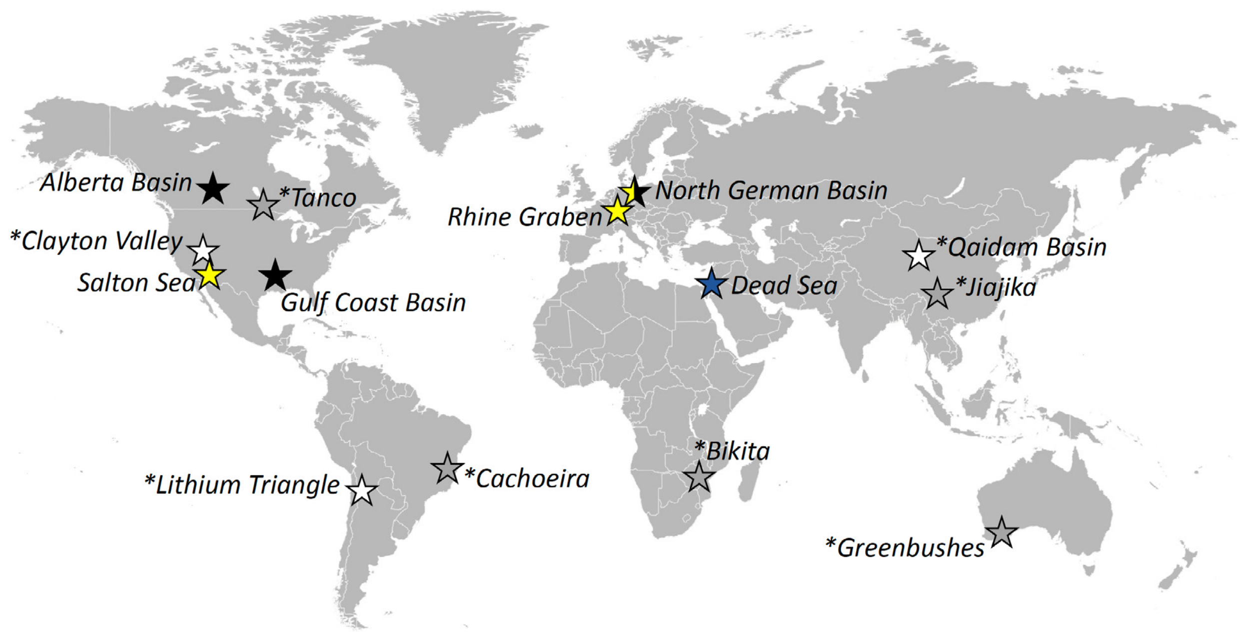

Figure 2. World map showing the locations of emblematic lithium production sites* and advanced projects (except for the Dead Sea), with color code for the main types of lithium resources as indicated in Figure 1. More complete information on lithium resources with or without active exploration/production projects and their precise locations are available from USGS (2024), Munk et al. (2025), Benson et al. (2025), and Brett et al. (2025). For pink lithium, see CAS (2025), showing the locations of lithium-ion battery recycling plants. Background political world map after Wikipedia Commons (2025).

process results in the emission of 3–4 tons of CO_2 equivalent and consumes 25–56 m^3 of freshwater (Kelly et al., 2021; Mas-Fons et al., 2024), not including the water evaporated during solar evaporation (100–300 m^3; Mousavinezhad et al., 2024). DLE requires industrial operations for extraction, purification, and conversion that emit the equivalent of 20 tons of CO_2 and consume 20–150 m^3 of water to produce one ton of lithium carbonate equivalent. However, freshwater can be recovered through the processing of Li-rich brines (Baspineiro et al., 2020; Mousavinezhad et al., 2024).

GRAY LITHIUM—MINES

This is lithium that is extracted from rocks in conventional open-pit or underground mines. By extension, gray lithium can also refer to lithium extracted from mining and processing residues. “Gray” refers to the light color of most lithium-enriched ores, such as pegmatites, granites, clays, and zeolites, which typically contain 0.6%–1.1% lithium. Unlike white lithium, gray lithium resources are found in varying amounts on all continents. However, current production is limited to pegmatite fields in a few countries, mainly Australia (Fig. 2). The quantities of water and energy required to extract gray lithium from pegmatites can be substantial due to mining, milling, and refining operations. It is estimated that producing one ton of lithium carbonate emits the equivalent of 15–22 tons of CO_2 and consumes 77 m^3 of water (Kelly et al., 2021; Mas-Fons et al., 2024). Furthermore, preserving water resources, landscapes, and ecosystems and managing mining waste are additional challenges to the social acceptance and further development of gray lithium.

PINK LITHIUM—RECYCLING

Pink lithium is obtained through recycling, primarily from lithium-ion batteries used in electric vehicles. Despite the boom in construction of recycling plants, the production of pink lithium is currently limited by technical challenges and the supply of battery waste (Neumann et al., 2022; IEA, 2024). Various studies suggest that pink lithium could supply 10%–60% of the raw material needed for lithium-ion batteries by 2035–2040 (Maisel et al., 2023; Zhou et al., 2024). While recycling preserves part of the resource, it is also an energy-intensive process that requires many chemicals. However, it is currently difficult to estimate the CO_2 emissions, energy consumption, and water consumption per ton of lithium carbonate produced by lithium-ion battery recycling processes that will be industrialized in the coming years due to the emergence of many different methods (Chagnes and Forsberg, 2023).

BLACK LITHIUM—OIL AND GAS

This is lithium dissolved at concentrations of up to a few hundred milligrams per liter in deep, nonpotable waters that occur naturally in hydrocarbon reservoirs. “Black” refers to the color traditionally associated with oil. Therefore, black lithium could be extracted from these groundwaters by DLE, with or without the co-extraction of hydrocarbons. Recent studies have revealed black lithium resources comparable in size to white and gray lithium resources (Dugamin et al., 2021; Knapik et al., 2023). Black lithium production could benefit from the infrastructure and investment capacity of oil and gas companies. It could also be coproduced with low-enthalpy geothermal energy, like yellow lithium (see below), or recovered during carbon capture, utilization, and storage operations in saline aquifers. Similarly, "black" lithium could refer to lithium extracted from coal fly ash (Qin et al., 2015). Several black lithium projects are currently in the advanced stages of development worldwide, particularly in Alberta (Canada), Arkansas (United States), and Germany (Fig. 2).

YELLOW LITHIUM—GEOTHERMICS

Yellow lithium is dissolved in warm water used for geothermal energy at concentrations of up to a few hundred milligrams per liter. The term "yellow" refers to the landscape of the world-renowned Yellowstone geothermal area in Wyoming. Substantial and well-distributed potential resources exist around the world (Toba et al., 2021; Gourcerol et al., 2024). Although several projects are well advanced in France, Germany, and California (Fig. 2), production of yellow lithium has not yet reached the large-scale industrial stage. Combining low-carbon geothermal energy with DLE may be attractive from environmental and economic perspectives (Weinand et al., 2023). However, controlling induced seismicity and ensuring the quality of groundwater during geothermal operations will be key factors in the social acceptance of yellow lithium.

BLUE LITHIUM—SEAWATER

Blue lithium refers to lithium dissolved in seawater and ocean water, which has an average concentration of 0.1–0.2 mg per liter. Blue lithium represents a huge lithium resource of ~230 billion tons (Yang et al., 2018). However, due to the presence of interfering ions (e.g., magnesium), extraction of blue lithium at such low concentrations is technically and economically challenging. Blue lithium may also be recovered from the Dead Sea (Fig. 2), where the lithium concentration reaches 30–40 mg per liter, as well as from seawater desalination waste brines (Alsabbagh et al., 2021; Zhang et al., 2021). Currently, there is no operational plan for the industrial extraction of blue lithium.

CONCLUDING REMARKS

Because resource inventories, technologies, and regulations are evolving rapidly, the background information and proposed color code provided here will need to be updated regularly, like the "colors" of hydrogen (Incer-Valverde et al., 2023). Since any industrial extraction or recycling of natural resources has a direct environmental impact, albeit to varying degrees, we recommend avoiding the potentially misleading term "green lithium." While a color code could facilitate communication and awareness in public debates, it is crucial to consider the pros and cons of each mining or recycling project on a case-by-case basis.

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