RESOURCE SCARCITY

Material efficiency to tackle the sand crisis

The world is facing a sand crisis, as booming sand use poses global sustainability challenges. A study now presents a blueprint for a less sand-demanding future, where synergistic material-efficiency strategies are crucial for curbing sand demand.

Zhi Cao and Eric Masanet

Sand is a key ingredient of concrete, asphalt, glass and silicon chips, all of which are indispensable for modern civilization. Of all end-use sectors, buildings are by far one of the largest sources of consumption of sand-containing materials globally[1]. Due to its abundant availability, sand is often perceived as an undepletable and renewable resource. So why is sand now deemed scarce? One might wonder, why not exploit sand from deserts and seas? This is because characteristics of unprocessed desert and sea sand cannot meet strict construction specifications for shape and chloride content[2]. Therefore, most of the sand that is suitable for construction projects is currently sourced from river beds[3], which account for <1% of the world's land[4]. Sand extraction is unregulated in many countries, posing significant threats to local ecosystems, infrastructure and livelihoods[2]. Driven by soaring needs for housing and infrastructure development, future sand demand is expected to double over the next four decades[2], which is likely to exacerbate the existing sand crisis. Writing in *Nature Sustainability*, Xiaoyang Zhong and co-authors cast light on the efficacy of material efficiency (ME) strategies to reduce sand demand and mitigate the global sand crisis[5].

ME strategies refer to technology and policy options that decouple material use from service provision[6]. As growing global demand for building materials puts ambitious climate and sustainability goals at risk, the importance of ME in mitigating the environmental impacts posed by building construction activities is becoming manifest and is increasingly recognized by researchers and policymakers[7–10]. Importantly, ME improvements can occur at various stages across the lifecycle of buildings (Fig. 1). To reduce sand use, critical ME strategies include sand substitution (with manufactured sand, desalted sea sand and processed desert sand), lightweight design, timber framing, more intensive use of building space, lifetime extension and concrete reuse. Although prior research has examined the efficacy of ME strategies in climate change mitigation[7–10], it remains unclear to what extent these strategies can curb booming sand demand moving forward. This knowledge gap persists in part because the data needed to project building-stock dynamics (stock additions and demolitions) and sand demand have been scarce. Zhong and colleagues help overcome this knowledge gap by utilizing an extensive database to explore possible avenues toward a less sand-demanding world.

As future sand use is closely tied with building-stock dynamics, Zhong and colleagues begin by developing a global stock-flow model that can examine how population growth, lifestyle and technologies would drive future dynamics in building stock. This dynamic model is grounded on the seminal work of Müller[11] and the continuous efforts thereafter, as summarized in a comprehensive review (see ref. [12]). The authors generate a large and extensive dataset to cover residential and commercial building stocks in 26 world regions. Crucially, using the amassed dataset, the original stock-flow model is enhanced with a more detailed representation of cross-building type and regional differences in sand use per floor area. This improved model granularity enables a better understanding of the potential of ME strategies to reduce sand use in buildings, as the applicability and efficacy of each strategy vary by building design and region.

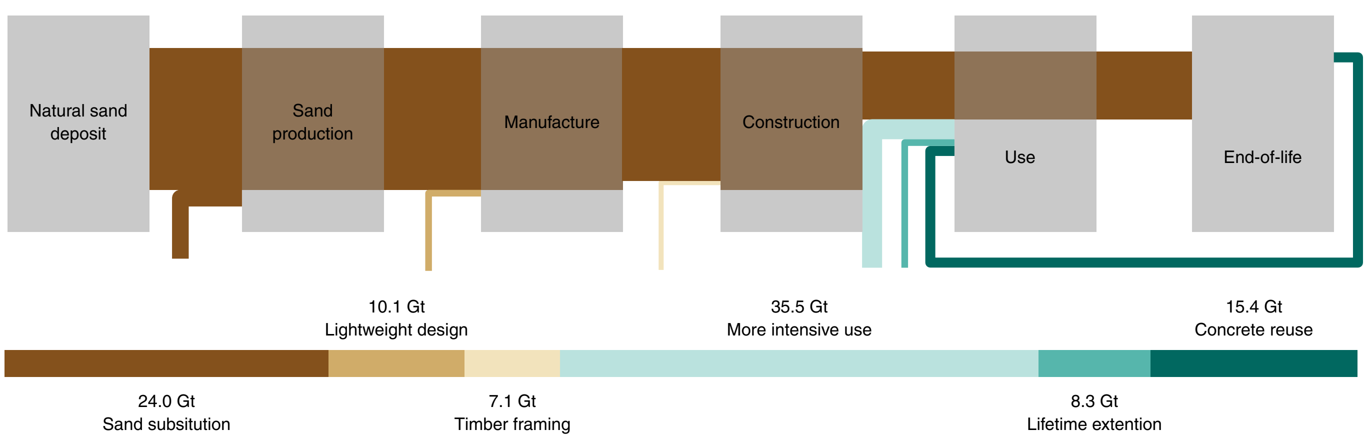

Fig. 1 | ME strategies for sand reduction across the lifecycle of buildings. Replotted based on the scenario results from Zhong et al.[5]. Numbers represent the cumulative sand reductions from each individual strategy during the period 2020–2060 and do not add up to the results of the '100% all' scenario, where all six strategies are simultaneously adopted.

To evaluate the extent to which ME can address the global sand crisis, the study of Zhong and colleagues simulates multiple scenarios, each of which represents a varying deployment level and combination of ME strategies. The baseline scenario reflects a middle-of-the-road future where socioeconomic trends broadly follow their historical patterns to 2060 (ref. [13]). In alternative scenarios, ME strategies are implemented independently or synergistically. In those synergistic scenarios, two adoption levels (that is, 100% and 50%) are explored to reflect the technical potential and envisaged readiness of ME strategies. The scenarios are based on detailed bottom-up assumptions on achievable targets for ME implementation. These assumptions are considered when projecting the newly constructed floor area, concrete use, glass use and sand use in different scenarios.

The results of the baseline scenario show that the present-day global sand use in building construction amounts to 3.2 Gt. Perhaps unsurprisingly, the world's insatiable appetite for sand will continue through the mid-century, with shifts from upper-middle- and high-income economies to lower-middle-income economies, particularly those in Africa. More specifically, the upper-middle- and high-income economies will take up >65% of the cumulative sand demand over the period 2020–2060, yet these economies are also expected to see eventual declines in annual sand demand. These declines are due to plateauing population and building-stock saturation in upper-middle- and high-income economies.

Notably, the confluence of all ME strategies results in substantial sand savings compared with the baseline scenario. If the full potential of all strategies is seized, global cumulative sand demand can be halved over the next four decades. Among all considered strategies, more intensive use stands out as the predominant driver of sand reductions, followed by sand substitution, concrete reuse, lightweight design, lifetime extension and timber framing. Interestingly, the role of ME strategies differs by region. For example, the contribution of more intensive use is more pronounced in Europe and the United States, where people generally have access to spacious buildings; lifetime extension, on the other hand, plays a less prominent role in Europe and the United States, as current building lifespans in these countries are already substantially longer than other countries. Although the analysis provides important insights on how likely the present-day supply capacity can sustain future regional sand demand if the potential of ME is fully realized, Zhong et al. stop short of providing the outlook for future sand supply due to the paucity of detailed data on sand trade and reserves. As such, there is a need to establish better monitoring programmes to gather and share data on global and local sand budgets — how sand is mined, traded and used, and how fast sand is replenished.

The analysis by Zhong and colleagues reveals the efficacy of ME strategies to tackle the global sand crisis. Given the urgency of the sand crisis, future research should address the governance challenges, technical roadblocks and transition issues associated with pathways towards a less sand-demanding future. Critically, greater international cooperation on sand trade, new construction codes and standards, and improved quality control of alternative sands will be key to influencing material changes to manage sand use in buildings. These ambitions will require collaborations among stakeholders along the construction value chain, inclusive of material producers, construction companies, architects, designers, waste managers and beyond. ❐

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Competing interests
The authors declare no competing interests.