From early cars to generative AI, new technologies create demand for specialized materials

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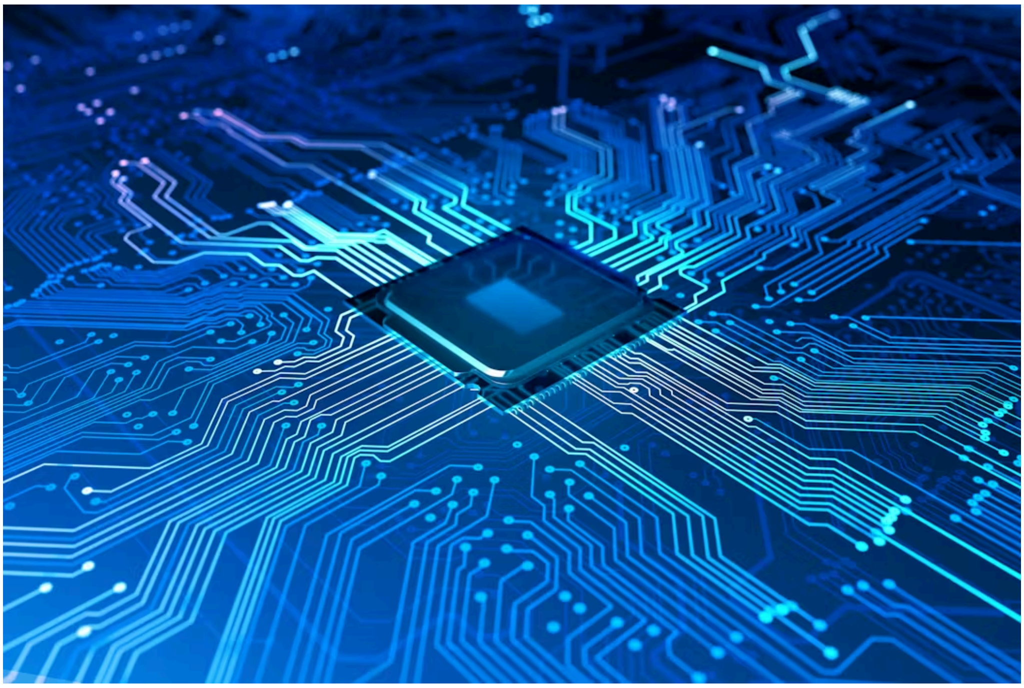

The development of new computing technologies drives the demand for improved materials.

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Generative artificial intelligence has become widely accepted as a tool that increases productivity. Yet the technology is far from mature. Large language models advance rapidly from one generation to the next, and experts can only speculate how AI will affect the workforce and peoples' daily lives.

As a materials scientist, I am interested in how materials and the technologies that derive from them affect society. AI is one example of a technology driving global change – particularly through its demand for materials and rare minerals.

But before AI evolved to its current level, two other technologies exemplified the process created by the demand for specialized materials: cars and smartphones.

Often, the mass adoption of a new invention changes human behavior, which leads to new technologies and infrastructures reliant upon the invention. In turn, these new technologies and infrastructures require new or improved materials – and these often contain critical minerals: those minerals that are both essential to the technology and strain the supply chain.

The unequal distribution of these minerals gives leverage to the nations that produce them. The resulting power shifts strain geopolitical relations and drive the search for new mineral sources. New technology nurtures the mining industry.

The car and the development of suburbs

At the beginning of the 20th century, only 5 out of 1,000 people owned a car, with annual production around a few thousand. Workers commuted on foot or by tram. Within a two-mile radius, many people had all they needed: from groceries to hardware, from school to church, and from shoemakers to doctors.

Then in 1913, Henry Ford transformed the industry by inventing the assembly line. Now, a middle class family could afford a car: Mass production cut the price of the Model T from US$850 in 1908 to $360 in 1916. While the Great Depression dampened the broad adoption of the car, sales began to increase again after the end of World War II.

Henry Ford at wheel, with John Burroughs and Thomas Edison in back seat of a Model T.

Bettmann/Contributor via Getty Images

With cars came more mobility, and many people moved farther away from work. In the 1940s and 1950s, a powerful highway lobby that included oil, automobile and construction interests promoted federal highway and transportation policies, which increased automobile dependence. These policies helped change the landscape: Houses were spaced farther apart, and located farther away from the urban centers where many people worked. By the 1960s, two-thirds of American workers commuted by car, and the average commute had increased to 10 miles.

Public policy and investment favored suburbs, which meant less investment in city centers. The resulting decay made living in downtown areas of many cities undesirable and triggered urban renewal projects.

Access to cars led to more spread-out neighborhoods, like this one in Milton, Ontario.
SimonP/Wikimedia Commons, CC BY-SA

Long commutes added to pollution and expenses, which created a demand for lighter, more fuel-efficient cars. But building these required better materials.

In 1970, the entire frame and body of a car was made from one steel type, but by 2017, 10 different, highly specialized steels constituted a vehicle's light-weight form. Each steel contains different chemical elements, such as molybdenum and vanadium, which are mined only in a few countries.

While the car supply chain was mostly domestic until the 1970s, the car industry today relies heavily on imports. This dependence has created tension with international trade partners, as reflected by higher tariffs on steel.

The cell phone and American life

The cell phone presents another example of a technology creating a demand for minerals and affecting foreign policy. In 1983, Motorola released the DynaTAC, the first commercial cellular phone. It was heavy, expensive and its battery lasted for only half an hour, so few people had one. Then in 1996, Motorola introduced the flip phone, which was cheaper, lighter and more convenient to use. The flip phone initiated the mass-adoption of cell phones. However, it was still just a phone: Unlike today's smartphones, all it did was send and receive calls and texts.

In 2007, Apple redefined communication with the iPhone, inventing the touch screen and integrating an internet navigator. The phone became a digital hub for navigating, finding information and building an online social identity. Before smartphones, mobile phones supplemented daily life. Now, they structure it.

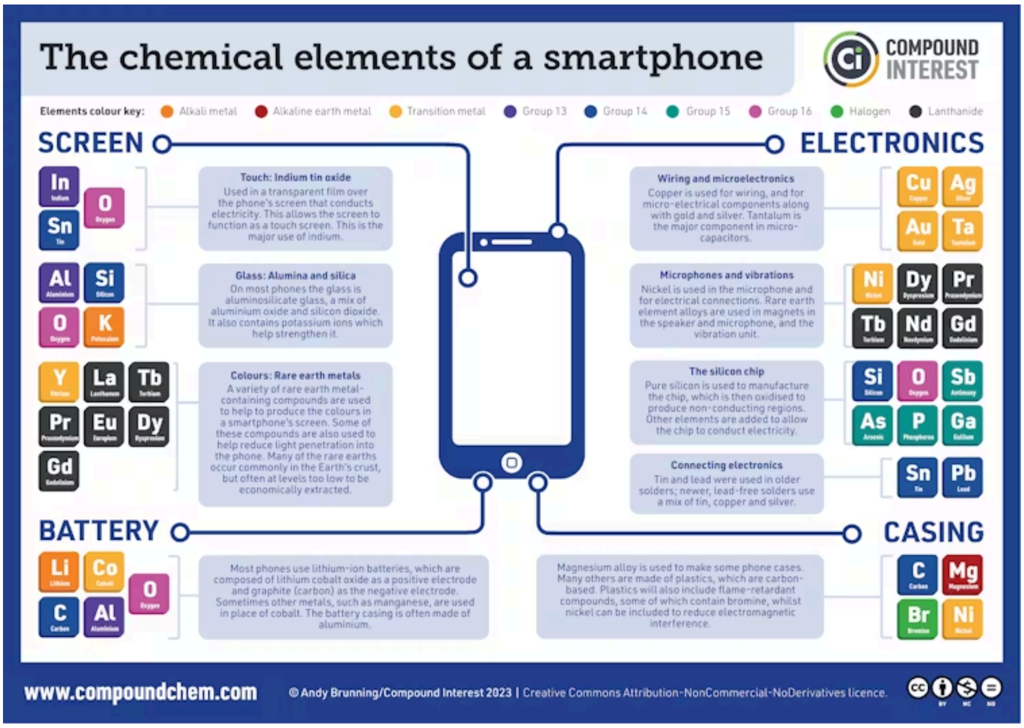
In 2000, fewer than half of American adults owned a cellphone, and nearly all who did it only sporadically. In 2024, 98% of Americans over the age of 18 reported owning a cellphone, and over 90% owned a smartphone.

Without the smartphone, most people cannot fulfill their daily tasks. Many individuals now experience nomophobia: They feel anxious without a cellphone.

Around three quarters of all stable elements are represented in the components of each smartphone. These elements are necessary for highly specialized materials that enable touch screens, displays, batteries, speakers, microphones and cameras. Many of these elements are essential for at least one function and have an unreliable supply chain, which makes them critical.

The Motorola DynaTAC 8000X was the first commercially available cellphone. With innovations and better materials, cellphones later became smaller, more lightweight and adopted touch screens.

Redrum0486/Wikimedia Commons, CC BY-SA



Smartphones contain around 80% of all known stable chemical elements, including some rare earth metals.

Andy Brunning/Compound Interest 2023, CC BY-NC-ND

Critical materials and AI

Critical materials give leverage to countries that have a monopoly in mining and processing them. For example, China has gained increased power through its monopoly on rare earth elements. In April 2025, in response to U.S. tariffs, China stopped exporting rare earth magnets, which are used in cellphones. The geopolitical tensions that resulted demonstrate the power embodied in the control over critical minerals.

Piles of rare earth oxides praseodymium, cerium, lanthanum, neodymium, samarium and gadolinium.

Peggy Greb/USDA-ARS

The mass adoption of AI technology will likely change human behavior and bring forth new technologies, industries and infrastructure on which the U.S. economy will depend. All of these technologies will require more optimized and specialized materials and create new material dependencies.

By exacerbating material dependencies, AI could affect geopolitical relations and reorganize global power.

America has rich deposits of many important minerals, but extraction of these minerals comes with challenges. Factors including slow and costly permitting, public opposition, environmental concerns, high investment costs and an inadequate workforce all can prevent mining companies from accessing these resources. The mass adoption of AI is already adding pressure to overcome these factors and increase responsible domestic mining.

While the path from innovation to material dependence spanned a century for cars and a couple of decades for cell phones, the rapid advancement of large language models suggests that the scale will be measured in years for AI. The heat is already on.

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