To reduce CO2 emissions, the materials industry needs to transition to a circular economy

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The transition to renewable energy is an essential part of the fight against climate change. But it will only address 55% of global greenhouse gas emissions. To achieve net-zero emissions by 2050, to meet the target set in the Paris Agreement, the remaining 45% of emissions from industry, agriculture, and land-use need to be addressed as well. The materials industry, which comprises companies that manufacture raw materials such as steel, aluminium, cement, and chemicals, is responsible for a large share of these remaining emissions and therefore has a key role to play.

Globally, the production of cement accounts for 8% of CO2 emissions, in the case of ammonia each tonne produced emits 2.6 tonnes of CO2, and for steel the ratio is 1:2. Overall, the materials industry is responsible for 27% of global CO2 emissions (including energy-related emissions). To reduce these emissions, the materials industry faces a limited number of options which may involve the use of low-carbon energy[1], low-carbon production processes, carbon capture, or material recycling. However, most of these solutions are neither effective nor available at scale.

In some parts of the industry, the use of low-carbon energy can only have a limited impact as most emissions come from chemical reactions (so-called 'process emissions') rather than the energy consumption during the production process. For instance, about two-thirds of the emissions of cement production result from calcination, the chemical reaction that occurs when limestone is exposed to high temperatures.

Most low-carbon production processes are still to be developed. Heavy industries have prospered for over a century using largely unchanged manufacturing processes. Steel has been made essentially the same way for thousands of years, by using carbon as a chemical reductant. Ammonia has been made for a century with the Haber-Bosch process that emits more CO2 than any other chemical-making reaction. Though capturing carbon from industrial processes and preventing it from entering the atmosphere is promising, most technologies either lack a clear business case or are not yet commercially available.

Of all the decarbonisation options, the use of recycled material is probably the most readily available. The production of recycled materials, by using different processes and consuming less energy than primary production, emits fewer greenhouse gases. For instance, the production of recycled aluminium is 97% less CO2 intensive than primary production.

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The demand for high-quality recycled materials to produce high-quality products is therefore likely to increase. For example, global steel conglomerate ArcelorMittal, at its plant in Fos-sur-Mer, France, plans to increase the amount of recycled steel it processes by a factor of five by 2025. BASF, the German chemicals producer, aims to process 250,000 tonnes of recycled and waste-derived raw materials annually as of 2025.

Yet, the supply of recycled materials is insufficient both in quantity and quality. Most of the materials entering the economy lose a large part of their volume and value after first use. For example, in the European Union, only 52% of the value of aluminium is preserved after one use. Quantity losses are due to materials that are not recycled. A large share of end-of-life materials are still disposed of in landfills, burnt for energy, lost in recycling processes, or never even enter the waste collection system. Quality losses are due to mixing different material grades and various forms of contamination during the recycling process. For example, contamination with copper can profoundly affect steel strength and quality. Much of the high-grade steel recovered from vehicles is downcycled into a lower-price material and mostly reused in lower-grade applications such as buildings and infrastructure.

To increase the quality and quantity of recycled materials, businesses can leverage a range of technologies to improve waste collection, sorting, and recycling. For example, Laser-Induced Breakdown Spectroscopy makes it possible to determine the composition of aluminium parts quickly and reliably during the sorting process. But technology won't be enough. A sufficient supply of recycled materials will require transformational changes to the materials industry that involve the adoption of new industrial ecosystems, business models, and supply chains.

Building new industrial ecosystems

Materials industries source raw materials from a few mining and exploration sites. By switching supply to recycled materials, they have to work with a more diverse and larger industrial ecosystem involving material suppliers, waste management firms, and recyclers. Sometimes, they even work in partnership with their competitors to share the costs and efforts of setting up such systems.

A few circular industrial ecosystems have already been established. In most countries, beverage cans circulate in a separate collection and remelting system, resulting in much lower value losses. In Germany, manufacturers of aluminium windows and doors, construction companies, and demolition firms are all members of the A|U|F association, which organises a closed-loop system for recycling the aluminium used in windows, doors, and façades. In Japan, the recycling company Harita Metals, in partnership with the Central Japan Railway Company, the rolling stock manufacturer Hitachi, and the recycled aluminium material manufacturer Sankyo Tateyama, have established a "horizontal recycling system" to provide materials from decommissioned trains to make new high-speed Shinkansen (bullet) trains.

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In the tyre industry, two major manufacturers, Michelin and Bridgestone, have decided to join forces to build a new industrial ecosystem. Today, less than 1% of all carbon black used globally in new tyre production comes from recycled end-of-life tyres; the remaining 99% is produced from virgin petrochemicals. Yet, using recycled carbon black in new tyre production would reduce CO2 emissions by up to 85% compared to virgin materials and reduce the tyre industry's reliance on petrochemicals. Michelin and Bridgestone seek to establish a coalition of a diverse group of stakeholders, including tyre manufacturers, carbon black suppliers, pyrolysis partners, and emerging technology start-ups, to increase the supply of recovered carbon black.

Offer solutions, not just materials

Automakers increasingly view their role as providing mobility and not just making cars. Clothing brands, leveraging new business models such as resale, rental, and repair, are creating new revenue without making new clothes. But, unlike many other industries, the materials industry has evolved very little during the last century. It still relies on the same business model, which sources, transforms, and sells materials. Yet, material companies could provide construction or manufacturing solutions rather than just materials, allowing them to better manage materials in closed loops and retain more of their value. Car manufacturer BMW collects old tungsten drill and milling bits at its plants in Germany and Austria to recycle them into new milling and drilling tools. Circulating tungsten in a closed loop in this way reduces CO2 emissions by more than 60%.

Other industries are also seeing opportunities. For example, the construction materials company Marubeni offers its customers the option to rent rather than buy steel girders and pipes for temporary steel constructions. Chemical company Safechem sells the service rendered by its solvents to clean metal parts, and not the solvents themselves which it collects after they have been used. Some metal refining companies are offering refining as a service to oil production plants. Refineries send their used catalysts to the refiner which recovers metals and returns them to the refinery for a new product cycle. By using these closed loops, over 90% of the precious metals contained in the catalysts are recovered, even in cases of life cycles of over 10 years.

Switching to these innovative business models is naturally challenging since companies will have to track their materials once produced. But emerging technologies, such as digital platforms, blockchain, and associated smart contracts could be leveraged to track materials. For example, Marubeni Corporation worked with a blockchain technology start-up, Circularise, to introduce a traceability management platform for the chemicals and plastics markets.

Shift freight transport from road to rail

Reusing and recycling industrial materials reduces emissions and energy demand in sectors where that is difficult to do. Designing new industrial ecosystems around the new business models needed to make this happen will also involve reducing emissions in areas where decarbonisation and energy efficiency is easier to achieve such as transport over land. For example, due to much higher energy efficiency combined with greater electrification and relatively low carbon electricity grids, in Europe transporting a tonne of freight by rail emits 29 gCO2 per kilometre compared to 137 gCO2 per kilometre for freight transported by heavy goods vehicle.

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At present, if raw materials are often shipped by train or barge to cement plants, chemical factories or steel mills, most recycled materials are shipped by truck. For example, in France, faced with the challenge of sourcing from 45,000 European scrap metal yards rather than from a few ore mines, more than 95% of scrap metal transport is carried by road.

However, many kinds of secondary materials, such as scrap and demolition waste, are particularly well suited to rail transport because of their weight, properties, or the way they are conditioned. For example, rail freight operator DB Schenker transports around 10 million tonnes of scrap every year, leveraging DB Schenker Rail's single-wagon network. Rail freight operator CFF Cargo transports up to 100,000 tonnes of metal scrap annually to recycling company Stahl Gerlafingen. By switching to rail, the company has avoided around 4,000 truck transports per year.

With its rail freight strategy to boost modal shift, the European Union set a bold ambition to double freight rail's modal share by 2030. This is an opportunity to attract recycling industries to rail. That would require some targeted investments, such as the establishment of sidings or direct access points to the rail network, measures to fully optimise last-mile management, the construction of freight wagons, and building loading and unloading stations for secondary materials.

Developing effective policies

Policy will play an important role in supporting transformational changes of the materials industry. However, it is not yet doing so. For instance, most policy targets are based on volume rather than value. Therefore, much of the infrastructure used for instance to demolish buildings or to shred and mix materials from end-of-life vehicles are optimised to meet these volume-based targets and are not necessarily conducive to the production of high-quality secondary materials. By supporting a circular economy for the materials industry, governments would not only reduce CO_2 emissions but also secure better access to raw materials. Today, Europe exports significant amounts of used materials and imports primary materials. Analysis shows that 82% of EU demand for aluminium, plastics, and steel could be met by recycling these materials. To support the transformation of the materials industry, policies could be implemented to deal with the negative externalities linked with the production of materials. For example, the actual cost incurred over the plastic lifecycle is at least 10 times higher than plastic's market price. Policies could also support the deployment of new technologies to collect, sort, and recycle materials, in line with the approach taken to support the development of renewable energy technologies.

Cement, a particular case

Transitioning to a circular economy will be more challenging for cement as, unlike steel, aluminium, chemicals, and glass, it cannot be recycled. However, there are some interesting alternatives. Clinker, an intermediary product in cement production and responsible for large quantities of CO2 emissions in its production, can be substituted by fly ash, a by-product of the energy sector, and granulated slag, a by-product of the steel sector. However, as the steel and energy sectors step up their own decarbonisation efforts, the availability of these substitutes will decrease. Some progress has also been made in recycling concrete recycling, the principal end product of cement. SmartCrusher bv (Netherlands based start-up) and Sika (Swiss chemical company) have developed a technique for recovering the sand, gravel, and cement from concrete, while Neustark (ready-mix concrete supplier) and Projet FastCarb (French national collaborative R&D project) have developed a technology to store CO2 in recycled aggregates.

As with all sectors, the heavy industries that make materials crucial to our lives need to design their products for a circular economy and, in doing so, build industrial ecosystems that run on new business models. Time is short: according to the IEA's Tracking reports, neither the iron & steel, cement, chemicals nor aluminium sectors are on track to achieve net-zero emissions by 2050. However, the promise of improved security of material supplies, greater industrial competitiveness, and lower energy demand make harnessing the circular economy to meet this imperative an attractive proposition for governments, industry, and wider society.

[1] Energy that is generated using lower amounts of carbon emissions such as wind, solar, or nuclear power.