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Future emissions from metal production can only be cut by circular economy

The most effective way to lower the greenhouse gas (GHG) emissions associated with metal production is to pursue a circular economy for the material in the long term, says a recent study. This century will see a high demand for seven major metals; the resultant overall environmental impact is expected to outweigh any environmental savings that may result from greener production processes or an increased use of renewable energy.

Natural resources are being extracted at an ever-increasing rate. This shows no sign of abating, raising concerns about whether resource supply will be sustainable in the future. Existing policies tend to address immediate problems related to the criticality of raw materials needed for economies and industries to function smoothly in the near-term. However, there is growing interest in taking a longer-term view of resource-related issues.

This study, conducted under the EU's Mineral Intelligence Capacity Analysis (MICA) project[1], developed and applied a method for assessing the future environmental impact of producing seven key metals: iron, aluminium, copper, zinc, lead, nickel, and manganese. It took a lifecycle assessment (LCA) approach and used data from the ecoinvent v2.2. database in order to consider several environmental impacts generated throughout the metal production and extraction processes: GHGs; energy demand; land use; depletion of abiotic (non-living) resources; and toxicity to aquatic ecosystems.

The researchers assessed how five key factors would influence these environmental impacts for the time period spanning 2010 to 2050:

1. changes in demand for metals;

2. the share of secondary (recycled) metals;

3. developments in ore grade (low-grade ores need more energy for extraction);

4. energy-efficiency improvements in production;

5. a greater share of renewable energy in the global electricity mix.

The results generally show gradual improvements in GHG emissions per kilogram of produced metal over the 40-year period, and conclude that moving towards a renewable energy system would have a major influence. For instance, although the energy demand per kilogram of primary aluminium is not expected to drop much, its GHG emissions per kilogram would change drastically — from 13.3 (2010) to 6.74 kilograms per carbon dioxide equivalent (kg/CO_2equiv) per kilogram of metal (kg/metal) (2050) — under a sustainable development scenario in which the share of renewable energy in the electricity mix increased from 33% to 88%. Energy-efficiency gains also contribute to this change for aluminium. Under a business-as-usual scenario, without a large renewable energy shift, however, primary aluminium's GHGs would drop to just 11.8/CO_2equiv per kg/metal in 2050.

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1. MICA (Mineral Intelligence Capacity Analysis) is supported by the European Commission's Horizon 2020 programme for research and innovation. See: www.mica-project.eu

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Conversely, changes in electricity mix have little influence on primary iron production. This is because iron's emissions derive from its use of coke (a coal-based fuel) in production for steel, and not from wider energy systems. Significantly reducing iron's future impacts is not possible unless a completely new, low-carbon production system is introduced, or the share of secondary iron is greatly increased, the study suggests.

Elsewhere, despite increased energy demand for extracting copper and nickel from increasingly low-grade ores, the emissions per kilogram for these two metals are expected to fall under sustainable development.

Despite per-kilogram improvements for many environmental impacts of these metals, overall impacts are set to increase due to increases in demand that offset the efficiency gains or benefits of renewable energy. Through efficiency improvements and greening of the energy system, the growth of these impacts can be lowered. For instance, although demand for aluminium and manganese is expected to triple under the sustainable development scenario, their GHG emissions would rise by a factor of only 1.2 to 1.5.

Secondary production of metals could be the most powerful influence of all in changing the impact of metals, the study suggests. This is already evident from the case of lead, which has a very high recycling rate that clearly lowers its impact.

The share of secondary metal in the resource mix is likely to be small over the 2010–2050 period due to the high growth in demand and long life-span of most metal products. However, from 2050 onwards more recovered metal will become available. Assuming a very high recycling rate of 90%, the researchers calculate that GHG emissions for aluminium and iron could start to fall between 2050 and 2100, in an absolute sense, under the sustainable development scenario.

The researchers acknowledge that a circular economy agenda for metals may appear huge and long-term, much like that for climate change. It would involve taking actions very soon to transform the whole materials cycle — from mining and production to product design to recycling infrastructure and technology — as well as pushing for policy that enables a circular economy. However, as it is the most effective option for reducing metal production's emissions, the researchers suggest that it is an agenda worth pursuing.