Essential Minerals for the Green Revolution – 2 Copper
An element for which the demand is increasing rapidly

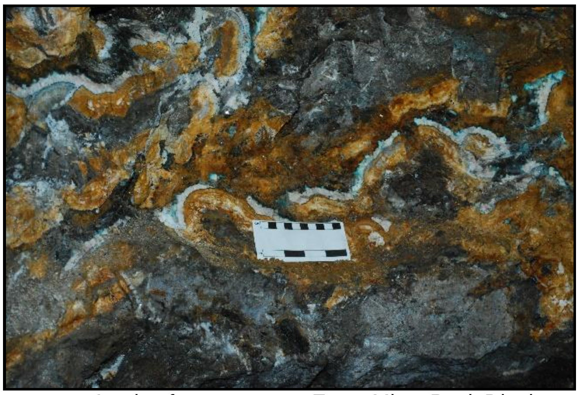
Humans have used copper for several thousand years, but demand for the metal has increased greatly recently, especially as the world seeks to reduce its carbon emissions. Replacing petrol and diesel vehicles with electric ones is seen as one way of reducing our carbon footprint. We shall look at copper as an example of the constituents of electric cars, and investigate where it comes from in the first place.

The elements needed to build an electric car (This graphic was used for the public understanding of science by Leicester University.)

The diagram shows the mass of each element which is needed to build a typical electric car: some of these elements are new to the motor industry. Copper is not a “new” element, but eight times more of it is needed in an electric car than in a petrol or diesel vehicle. Copper is a major constituent of the lithium-ion battery, as well as being needed for the windings of the electrical motor and other electrical components. And of course, many other modern industries have an increasing demand for copper, as well as the motor industry.

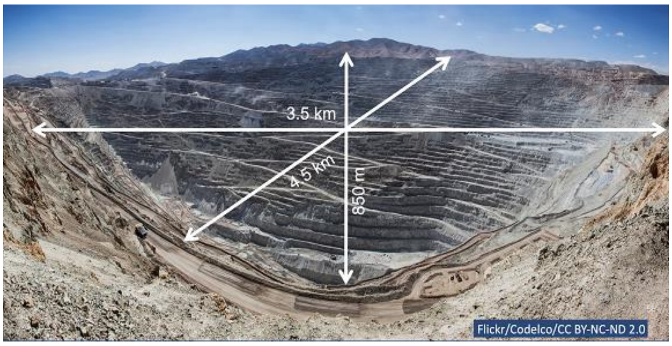
53kg of copper are needed in a typical electric car. As demand for copper rises, ask pupils where sufficient sources might be found? Ask them to study the photographs below before reading on.

A scrap yard in the USA (*Wikipedia, Public domain*)



A vein of copper ore at Ecton Mine, Peak District

The remains of opencast mining for copper ore, Anglesey



The copper mine at Chuquicamata, Chile

a) Recycle copper from scrap? b) Re-open old mines in the UK, e.g. Parys Mountain in Wales, or Ecton Mine in the Peak District? c) Expand existing huge copper mines in North and South America? d) Prospect for new deposits in former convergent plate margins?

Recycling copper from scrap is important and more than 50% of copper in end-of-life products is recycled from scrap, but it is not enough. Old mines in the UK are far too small-scale for modern needs and the copper is mostly worked-out, or too costly to consider mining again. So this leaves expanding existing huge mines and prospecting for new deposits, i.e. mining on a vast scale is the only way in which we can find enough copper for electric cars and a host of other uses.

But, modern large-scale copper ore bodies are of very low-grade ore, e.g. around 0.4% of the mined material is actually copper metal when it is refined: 99.6% is waste.
What problems might be caused by this very low ratio of copper to the ore? (*disposal of vast quantities of waste material; environmental issues such as water and air pollution; displacement of the local population etc).*
Calculate how much waste rock would be left in extracting just 1kg of copper, from an ore of only 0.4% grade.
4 g of copper is produced from 1000 g of ore.
1000 g of copper is produced from 1000/4 x 1000 = 250,000 g of ore (250 kg)
so the waste = 250 kg – 1 kg = 249 kg
If an electric car contains 53 kg of copper, how much waste would be left after extracting the copper?
53 x 249 = 13,197 kg = 13.2 tonnes.
How much space would this amount of waste take up? Assume that the waste material has a density of about 2.5 tonnes per cubic metre.
Volume of waste = $\frac{13.2}{2.5} = 5.3\ m^3$
To find out what this would look like, measure a space 2.4 m long by 1.5 m high x 1.5 m wide (= 5.4 m^3)
For comparison, the smallest Smartfortwo™ car measures 2.5 m x 1.5 m x1.5 m

Although the waste would almost fill a very small car, it is not solid rock. To extract the copper, the ore is crushed and ground down to a fine powder and then pumped through tanks in water. Chemicals added to the tanks attract the copper minerals in bubbles, which float up and can be scraped off. This process is known as froth flotation. It results in a wet slurry of fine waste, which is pumped into vast lagoons, called tailings dams to settle.

A Smartfortwo™ car

A well-constructed tailings dam, Fort McMurray, Alberta, Canada (*Public domai*

Devastation caused by the collapse of the Brumadinho tailings dam, Minas Gerais, Brazil, in 2019
(*This file is licensed under the Creative Commons Attribution-Share Alike 2.0 Generic license*)

Unfortunately, tailings dams are liable to burst their banks and can cause widespread damage to the local environment. In 2019 a tailings dam at Brumadinho iron ore mine in Brazil burst and released 12 million m^3 of material in mudflows which swept down the valley below, killing 270 people and much livestock, carrying away a railway bridge and contaminating water supplies. It is estimated that by 2050 the demand for copper, worldwide will treble, compared to 2023, but the grade of copper ore will be half that of today. Why? *Because lower grade ores will have to be used as higher grade ones are depleted.*

Discuss how the countries where copper and other ores are mined could lessen the impact of mining on their communities. *Try to keep the workings at a distance from population centres, build adequate infrastructure for the works, ensure any tailings dams are safe and spills can be contained* . . . .)

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The back up

Title: Critical minerals – 2 Copper

Subtitle: An element for which the demand is increasing rapidly

Topic: An investigation into the need to increase mining for copper as demand rises abruptly and ores of lean (low) grade have to be used.

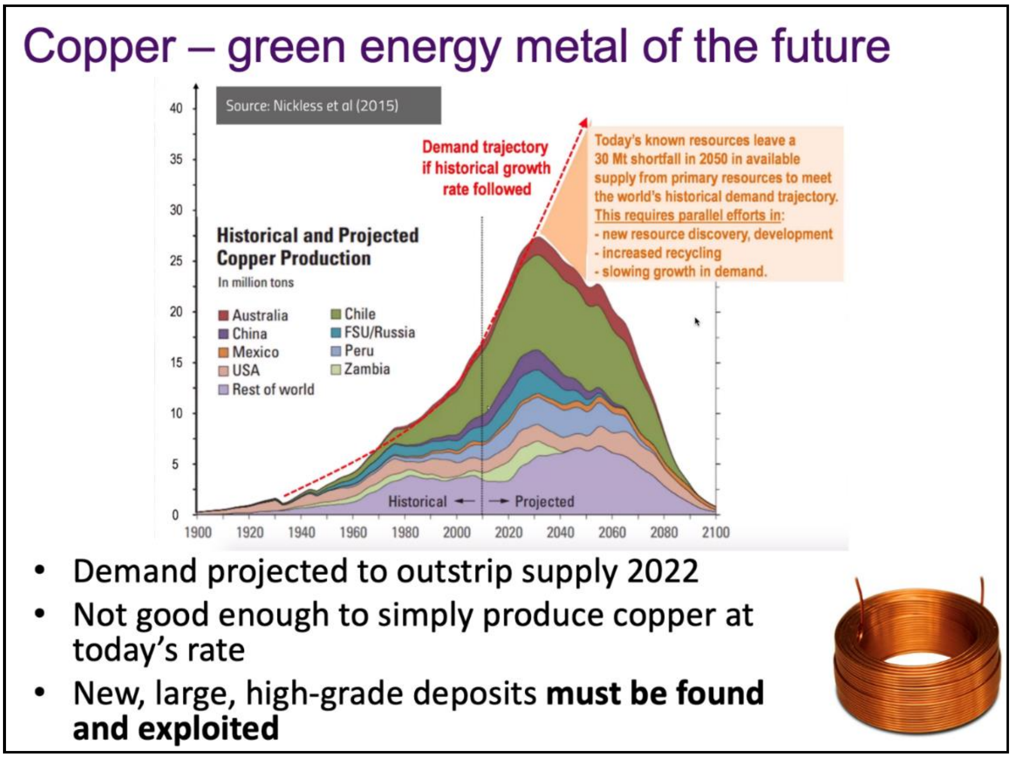
Age range of pupils: 12 years upwards

Time needed to complete activity: 30 minutes plus any time to carry out a web search

Pupil learning outcomes: Pupils can:
- explain why so much more copper is needed as new technologies are employed to counter the rise in carbon emissions;
- evaluate different possible sources of copper;
- explain why there is no alternative to mining to meet current and future demands for copper;
- calculate approximate quantities of waste when copper is extracted from the ore;
- discuss the impact of large-scale copper mining on local environments and communities and suggest mitigating factors;
- appreciate that copper is just one of many industrial minerals where demand is rising rapidly across the world.
- If the suggested follow-up activity is used pupils should be able to debate the implications of the supply of copper for their own country.

Context: This activity could be used in a lesson on the need to identify and exploit copper minerals in vital applications in many different fields, including electric motors, wiring, lithium-ion batteries, power transmission, alloys such as brass. Worldwide demand for copper and related metals is rising rapidly as new technologies are embraced.

Following up the activity: Pupils could carry out a web search for more information and for staying up to date, since the situation is changing rapidly. They could use the diagram below to discuss the implications of supply and demand for their own country.



Underlying principles:
- Worldwide demand for copper is increasing rapidly with the growth of new technologies.
- Existing technologies also require more copper as world population increases.
- Known copper ores are of diminishing grade, so more prospecting and more mining must take place to keep pace with demand.
- Mining and processing techniques have a major impact on the surrounding landscapes and on the people who live there.
- Waste disposal, especially tailings dams, also take up a great deal of space and introduce hazards which must be managed properly.
- This case study has focused on copper, but similar principles apply to other metals such as cobalt, nickel etc.

Thinking skill development: Establishing the worldwide demand for copper and the need to extend the mining of it involves construction. Metacognition is involved when the impact of mining is discussed. Applying thinking to new contexts is a bridging skill.

Resource list:
- access to the photographs in this activity, or the equivalent on the web

Useful links: https://post.parliament.uk/research-briefings/post-pb-0045/
https://www.earthlearningidea.com/home/Mining_Green_Revolution.html

Source: Written by Peter Kennett of the Earthlearning idea team
Graphic "Copper – green energy metal of the future" from:
https://www.researchgate.net/figure/So-called-Hubbert-curve-for-global-copper-production-from-model-calculations-An-output_fig1_354557045
It is Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International
Chuquicamata mine: courtesy of the Geological Society of London.
https://www.geolsoc.org.uk/Education-and-Careers/Resources

Note: This activity was as accurate as possible in spring 2023. Rapid developments are taking place in the technology of low and renewable energy.

Essential Minerals for the Green Revolution

Earthlearningidea has compiled a series of activities on the minerals which are essential if modern technology is to be able to reduce the World's carbon footprint. Some are regarded as "critical" minerals and many of them are relatively "new" in terms of needing to be exploited.
This table will be updated as fresh activities are added.
All titles begin with: Essential Minerals for the Green Revolution…

Mineral	Title
Lithium	1 Lithium: an element which is pulling more than its weight in the world
Copper	2 Copper: an element for which the demand is increasing rapidly
Rare Earths	3 Rare Earth Elements: vital components in modern technology
Graphite	4 Graphite: from a pencil to the electric car!
Cobalt	5 Cobalt: mined by children
Tin, Tungsten, Tantalum	6 "The Three Ts": Tin, Tungsten and Tantalum
Gold	7 Gold: an essential mineral - or is it?
Critical minerals	8 Critical Minerals: Essential mineral - critical mineral: what is the difference?