Steel without the fossil fuels activity sheet 39 Ways to Save the Planet

Royal Geographical Society with IBG
Advancing geography and geographical learning

Could there be 'green steel'?

This is a resource linked to the BBC Radio 4 programme *39 Ways to Save the Planet*. Listen to the episode Steel without the fossil fuels and complete the tasks below.

This teaching resource is on the challenges facing the global steel industry and the ultimate goal of producing green steel in the twenty-first century. It is an important industry to target as steel is an extraordinary strong alloy of iron and carbon which 'makes much of the skeleton of our world today'. However, it accounts for a large chunk of our global carbon dioxide emissions (between 5 and 8%) as we produce 1.8 billion tonnes of steel per year worldwide — that's 250kg of steel per person per year. To combat this a new joint venture in Sweden might pave the way for green steel in the future.

How is iron ore converted into steel?

Iron ore is crushed, sorted, and melted in coal-fired furnaces to produce iron oxide pellets for the steel industry. The oxide (oxygen) is removed in the reduction work of a blast furnace (shown below) when coke, iron ore and limestone are heated to produce pig iron. This releases carbon dioxide (CO_2). Pig iron is an intermediate product which is then converted into steel in a basic oxygen furnace (when oxygen is blown through it to change it into low-carbon steel).

Steel production is extremely energy intensive as it requires high temperatures (approx. 1650°C) to 'cook' coal into high energy value coke (needed to melt the iron ore). This releases carbon monoxide (CO). Heavy machinery is also required for mining and production. At the end of the process the molten steel is poured into a ladle whilst limestone and iron ore impurities are collected as waste products, called steel slag.

Blast furnace © Zephylwer Pixabay

Kiruna mine, Sweden

Nearly 150 kilometres north of the Arctic Circle is Kiruna, in Lapland, Sweden. Kiruna is an Arctic mining town of 17,000 people, located next to the largest and most continuous iron ore deposit in the world. It is purpose-built for the workers of the Kiruna mine. The mine goes down 1365m below the old top of the mountain with a huge range of infrastructure beneath the Earth's surface. Kiruna has been operating since 1890 with only one-third of its iron ore extracted so far. This is problematic because the extraction of iron ore and the production of steel is intertwined with the burning of coal.

NASA Landsat of Kiruna and the LKAB mine www.earthobservatory.nasa.gov/images/89010/kiruna-iron-mine

The Kiruna mine now threatens the structural integrity of the town of Kiruna. Due to growing concerns over subsidence a project began in 2021 to move the whole town 2-miles away. The expected completion date is 2035. The final trigger for the relocation was a significant earthquake in Kiruna in 2020, thought to be due to the industrial scale of mining in the area.

1. Go to Google Earth and search for Kiruna, Sweden. Zoom in and screenshot the satellite image. Using this Guardian article, can you locate: Kiruna city centre, the proposed new site, the mine spoilt tip, and mine entrance?

2. Continue to use Google Earth. Click the 3D button on the right of your screen. Can you locate the giant surface crack which is rapidly becoming a sinkhole?

HYBRIT

In Sweden, the mining company of Kiruna LKAB, the Swedish electricity company Vattenfall, and SSAB have joined forces to create the HYBRIT initiative (Hydrogen Breakthrough Ironmaking Technology) which aims to radically reduce CO_2 emissions. The aim is to invent zero-carbon mining and steel production. Everything from machinery to replacing coal (coke) with hydrogen is being researched and invested in with the goal of producing green steel in the twenty-first century.

Currently the HYBRIT project have two power plants, one of which has been converted to running on biofuel (still in test phase). The stated aim is to burn hydrogen instead of oil in the future. A new plant in northern Sweden has been built with an electrolyser to split water (H_2O) into hydrogen and oxygen.

Green electricity is fundamentally important because producing hydrogen requires very high amounts of energy. Therefore, Vattenfall are an important stakeholder. A pilot hydrogen plant is in operation producing a ton of steel per hour.

Equally, it is also hoped that the electric arc furnace will be utilised more in the future, as an alternative to the blast furnace. This is because the blast furnace emits between 1.6 and 2 tonnes of CO_2 per ton of steel produced whilst the electric arc furnace can be as low as 0.2 tonnes of CO_2 per ton of steel.

There are many benefits of adopting fossil-free fuel for the steel industry such as greater automation and digitalisation to improve productivity and increases in efficiency (from a circular economy). It is a perfect time to invest in pursing green steel because much of the steel plant infrastructure in Europe is outdated, requiring investment.

3. Is there a link between the location of steel sites and coal mines in the UK? Use the UK steel sites map from MAKE UK and the UK Coal Authority interactive map viewer (zoom in for more functionality) to map the geography of these two UK industries.

Further reading

- Kiruna: A Mining Town on The Move In Northern Sweden www.forbes.com/sites/davidnikel/2021/03/23/kiruna-a-mining-town-on-the-move-in-northern-sweden/?sh=5ee4cc684080
- Sweden's Kiruna mine forces residents to relocate www.youtube.com/watch?v=4H2wpGrxZuM
- NASA Landsat imagery www.earthobservatory.nasa.gov/images/89010/kiruna-iron-mine
- The Sami and Kiruna www.theguardian.com/cities/2018/dec/02/kiruna-swedish-arctic-town-had-to-move-reindeer-herders-in-the-way
- The next big green thing www.bloomberg.com/opinion/articles/2021-03-25/the-next-big-green-thing-steel
- Iron and steel www.bloomberg.com/opinion/articles/2021-03-25/the-next-big-green-thing-steel
- Cleaning up steel is key to tackling climate change www.ft.com/content/3bcbcb60-037f-11e9-99df-6183d3002ee1
- ArcelorMittal www.ft.com/content/d61df553-ae4a-4311-95fc-9d40861ac9bd
- Using hydrogen risks locking in reliance on fossil fuels www.theguardian.com/environment/2021/may/06/hydrogen-fuel-risks-reliance-on-fossil-fuels

- Climate change: Net-zero cannot be achieved by planting a few trees or keeping lights switched off a bit more news.sky.com/story/climate-change-net-zero-cannot-be-achieved-by-planting-a-few-trees-or-keeping-lights-switched-off-a-bit-more-12283818

Suggested questions for Steel without the fossil fuels

a. Where is the Kiruna mine located?

b. Describe the process of transforming iron ore into steel.

c. By 2026 what amount of steel will be produced using hydrogen in the HYBRIT pilot power plant?

d. What is the danger about 'dirty steel' from India and China?

e. How will this change the geography of the steel-making process near coal mines?

An RGS-IBG expert

Go to What our expert says to hear further analysis from Dr Tasmin Edwards, and FRGS Chris McDonald on the potential of fossil free steel production in reducing carbon emissions. Image courtesy of Materials Processing Institute.