Climate ambitions and metal needs

– opportunities for Sweden and the Swedish mining industry

SveMin

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Project: Society's future needs for metals and minerals for a sustainable and digital society in a 2030 and 2050 perspective.

September 2021

About this report

Material Economics has performed the collection of facts and analysis of data on behalf of Svemin. Authors at Material Economics are Karl Murray and Per Klevnäs. Svemin has conducted the interviews in the report. The original report was produced in Swedish, while a third party created the English translation.

The report was produced within the framework of the project *Society's future needs of metals and minerals for a sustainable and digital society in a 2030 and 2050 perspective*. Svemin is the initiator and project owner of the work, which lasted from December 2020 to August 2021.
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SWEDISH MINING INNOVATION

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Copper is a critical metal for the climate transition, as it lays the foundation for all electrification in society. Boliden's smelter Rönnskär in Skelleftehamn is one of the world's most efficient copper smelters. Rönnskär receives concentrates of lead and copper both from its mines and from external suppliers. The smelter is also a world leader in the recycling of electronics.

The climate transition is entirely dependent on access to metals. A traditional passenger car contains about 20 kg of copper. An electric car contains about 70 kg of copper.

Foreword

The climate transition requires access to metals and minerals

We are facing an unprecedented climate challenge. The UN's climate panel IPCC sounds the alarm in its latest report and shows that the ongoing climate transition is more extensive and faster than the most gloomy forecasts. How the world acts in the next few years will be crucial in avoiding even more catastrophic climate effects. However, phasing out fossil energy sources and replacing them with alternative sources creates challenges. In the EU's industrial strategy, the European Commission points out that the transition risks replacing the reliance on fossil fuels with dependency on metal and mineral raw materials. They are absolutely right.

Wind turbines, solar panels, batteries, electric cars – most of the technologies that will help us switch to climate neutrality require that we have access to metals and minerals. The question is: how much metals and minerals will be needed to achieve political climate goals, and how much of this need can be met by recycling?

Several studies and reports have attempted to predict society's future needs for metals and minerals in recent years. Some studies have focused on the energy transition and electrification, while others have taken a broader perspective and included infrastructure construction and other societal needs. However, Svemin has seen a need to get an overall scientific picture of society's future demand for metals and minerals, linked to Sweden's potential to contribute to meeting that need. We, therefore, asked Material Economics to carry out such an analysis, their conclusions you now hold in your hand. This knowledge is essential to enable robust, strategic decisions linked to Sweden's and Europe's raw material supply and pathway towards a fossil-free future.

One conclusion from Material Economics is that the climate transition will be the most influential single driver for increased demand for most metals until 2050. Consequently, the level of ambition set for the climate transition will significantly affect demand for these metals. A faster transition to a net-zero society will thus mean higher demand for metals. At the same time, the analysis also shows that recycling is essential. However, recycling expects to cover less than 15–26 percent of the emerging demand up to 2050.

The Swedish mining industry is at the forefront globally of sustainable mining. The climate footprint of metals produced here in Sweden is already low in a global comparison, and the goal is to be completely fossil-free by 2045. With increasing metal demand, it becomes even more critical to produce metals for the climate transition in a climate-smart way – products that Sweden's mining, mineral, and metal producers can provide.

Stockholm, september 2021

Maria Sunér
CEO, Svemin

Katarina Nilsson
Director Research and Innovation, Svemin

Maria Sunér

Katarina Nilsson

For the majority of metals, the most important single driver of increased demand in the period up to 2050 will be the climate transition.

Under our feet are resources critical for our society, such as iron and copper. There are metals and minerals for batteries, like cobalt and graphite. In addition to this, there are rare earth metals needed for wind turbines and other renewable energy technologies. These are all raw materials that are a prerequisite for the green transition.

Summary

Metals and minerals are raw materials of unique importance to society and the needed transition to a sustainable net-zero economy. This report brings together an updated perspective on the future demand for metals and minerals, the impact of the climate transition on metal needs, the supply outlook, and implications for Sweden and the Swedish mining industry.

By 2050, global demand for all the metals and minerals included in this report are expected to grow. For many metals, demand will rise substantially by 2050 – demand for lithium, rare earth elements, graphite, and indium, for example, are expected to increase at least fivefold.

Many factors affect the demand for metals, such as economic development, urbanisation, the metal intensity of our economy, and the recycling rate, to name a few. For many metals, the most critical driver increasing demand up to 2050 will be the climate transition. The climate technologies that underpin the transition to a sustainable society, such as wind power, solar power, electric cars, and batteries, all require metals to a great extent, and often new metals that have not been used on a large scale so far. In addition, climate change will require a sharp increase in the electrification of society, which in turn will require more metals, especially copper.

These so-called energy-critical metals include lithium, cobalt, nickel, indium, and rare earth metals. Lithium, cobalt, and nickel are metals needed to make batteries for electric vehicles and energy storage. Solar cells use indium while, for example, wind turbines and electric motors use rare earth metals. For these metals, more than half of the future demand will come from climate technologies. Thus, the level of ambition in the climate transition strongly affects demand - a faster changeover to a net-zero society means higher demand for metals.

For Europe, these effects are expected to be particularly significant, with demand for metals growing even faster than globally. This is because Europe has high climate ambitions and thus expects faster build-out of the technologies that will require metals, plus that our technology mix is somewhat different.

90 percent of the iron produced in Europe comes from Sweden.

To meet this growing need for metals - recycling, reuse, and other circular methods are often highlighted as solutions. Our analysis shows that these measures are essential and can significantly affect the future demand for primary metals, but they are insufficient to meet the entire market. For the metals analysed in this report, improved recycling can reduce the need for primary metals by about 15–26% by 2050.

The majority of metals required up to 2050, therefore, needs to be sourced through mining. However, for the EU, this is a challenge as the region is highly dependent on imports for many metals.

Today, the EU imports 100% of the rare earth metals molybdenum and titanium and almost the entire demand for graphite, manganese, lithium, and cobalt. In addition to increased supply risks, the EU also loses the opportunity to build important value-chains around these metals and the climate technologies they enable.

> Most of the metals needed up to 2050 therefore need to come from mining.

For Sweden, this means an opportunity to provide metals from Swedish mines and metals produced in a more sustainable, environmentally friendly, and socially responsible way than other parts of the world. Today's metal market is entirely global since the value of the resource is very high compared to the transport cost. Metals will be mined somewhere, if not in Sweden, then in other parts of the world. The Swedish mining industry has a lower climate footprint than other regions, and its metals exports create a significant climate benefit of approximately 5 million tonnes of CO2 per year. The industry expects this climate benefit to grow further based on the improvements already planned.

Sweden has a long and solid history of mining and is a significant mining country in Europe, contributing, for example, to more than 90 percent of the production of iron. Sweden has the potential to extract many new and important metals and minerals. There are known deposits of rare-earth metals, graphite, cobalt, lithium, nickel, platinum group metals, titanium, and vanadium. Graphite and rare earth metals are ready to be mined on a larger scale from Swedish deposits awaiting permission. In summary, this means that Sweden has excellent opportunities to continue refining and developing a leading industry, meeting a growing demand critical for the climate transition, and contributing with metals and minerals extracted sustainably.

Society's need for metals and minerals is expected to grow significantly up to 2050

Metals and minerals meet a fundamental need in our society. Our economy uses metals and minerals for their unique strength, hardness, electrical or thermal conductivity, or magnetic or chemical properties regardless of industry or area. The economic development of our society has gone hand in hand with the increased use of metals and minerals. As countries develop, they generally go through a phase in which the need for metals increases significantly to construct buildings, infrastructure, cars, and the other characteristics of a developed economy. Demand then tapers off and can be met to a greater extent from recycled metals. Today, many parts of the world have gone through this phase of development. At the same time, there is still a large unmet need for metals in much of the world. For example, less than one tonne of steel is used per capita in Africa, while the OECD countries have reached a saturation point at around 11–14 tonnes per capita (Material Economics, 2018). So how is the demand for metals going to develop in the future?

This report compiles the results of multiple studies looking at the use of metals and minerals up to 2050. It includes meta-studies containing over 150 underlying forecasts of the future need for metals. Figure 1 brings together the current production of primary metals (from mining), historical growth, and an average of various growth forecasts up to 2030 and 2050, as well as the assumed uncertainty.

Several conclusions are clear.

1. All metals and minerals will see increased demand up to 2050.
2. The greatest growth observed is among the so-called energy-critical metals lithium, rare earth elements (REEs), graphite, indium, and cobalt, which are expected to

> Regardless of industry or area, metals and minerals are used for their unique properties.

Figure 1. Expected global growth in demand for selected metals and minerals up to 2050

Lithium, rare earth elements (REEs), graphite, indium, and cobalt are among the metals and minerals with the highest expected growth up to 2050. Of the metals with a large production today, copper is expected to g

● Higher uncertainty ◔ Lower uncertainty

	Global production 2018 (Thousand tonne primary metal per year)	Historical growth 2008–2018 (Percent)	Outlook – average of existing forecasts[1]: Growth to 2030 (Percent)	Growth to 2050 (Percent)	Uncertainty[2]
Iron (Fe)	1,340,000	35	13	25	◔
Aluminium (Al)	62,700	59	24	75	◔
Chromium (Cr)	40,800	75	16	47	◔
Copper (Cu)	20,600	33	94	188	◑
Zinc (Zn)	12,400	6	34	74	◑
Titanium (Ti)	4,800	-25	19	15	◔
Lead (Pb)	4,800	20	25	73	◑
Silicon metal (Si)	2,870	72	325	N/A	◕
Nickel (Ni)	2,233	46	73	212	◕
Graphite (C)	1,000	-52	165	494	◑
Molybdenum (Mo)	276	24	-2	4	◑
REE[3]	196	55	300	617	◕
Cobalt (Co)	168	158	67	346	●
Lithium (Li)	117	468	327	691	◕
Vanadium (V)	84	25	63	189	●
Silver (Ag)	28	30	61	218	◑
Indium (In)	1	60	304	419	◕
PGM[4]	0.5	2	100	300	●

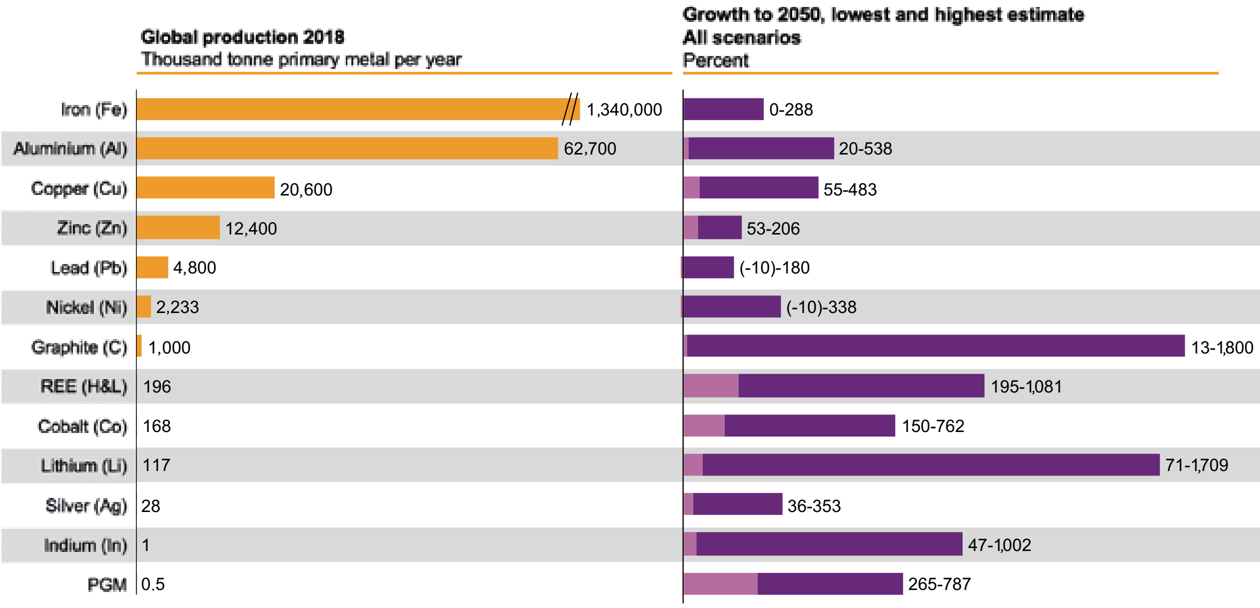
1 Average of forecasts from literature search, as far as possible linked to the 2-degree target and with circularity.
2 The uncertainty reflects the difference in demand between forecasts.
3 Rare earth elements.
4 Platinum group metals.

grow by 300%. The common factor is that these metals and minerals have not been used on a large scale before, with the technologies which use these being relatively new and under rapid development.

3. The base metals – iron, aluminium, copper, zinc, and lead – will grow by 25–188%. These metals are already in wide circulation in our economies, and their further growth will not be as significant. Of these, copper is the metal with the highest expected growth.

When forecasting the future, there is always great uncertainty and variation between studies. The differences arise from different methodologies, different scenarios for technical and economic development, and different assumptions concerning recycling and other trends. Examples of individual factors that have a significant impact on demand in the literature include the pace of the climate transition, economic development and urbanisation in emerging economies in regions such as India and Africa, as well as technological development that affects the metal intensity and opportunities for recycling, reuse, reduced resource consumption, and other circular measures. Figure 2 summarises the difference between the highest and lowest estimates in the literature. An examination of what causes the difference for each metal and mineral is outside the scope of this report. However, one example is graphite – demand expects to grow due to demand for electric vehicles and batteries. Here, the big difference is mainly due to the predicted market share of electric vehicles, what proportion of battery technologies use graphite, and the extent to which mined graphite is used rather than synthetic graphite.

Figure 2. Difference in growth between the lowest and highest estimate
There is a wide spread in estimates of the future need for metals and minerals.



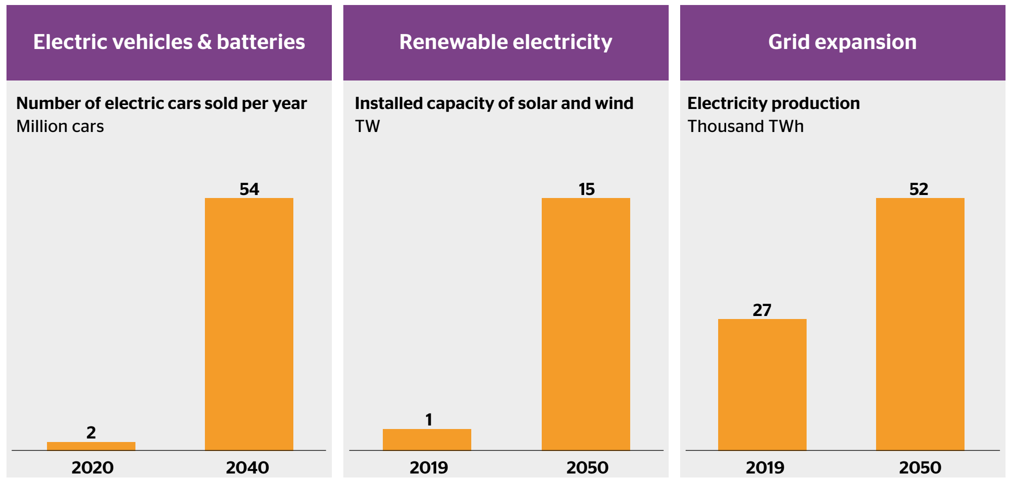
Higher climate ambitions increase the need for metals

Many trends and societal changes affect the need for metals. The climate transition will be the most important factor up to 2050, particularly for the energy-critical metals. This is perhaps not surprising when we consider that the climate transition is likely to be the most significant transition of our economy since the industrial revolution, with implications for all sectors of our society.

Three changes associated with this transition will have a substantial impact on the need for metals: the shift to electric vehicles with batteries, the expansion of renewable electricity (particularly solar cells and wind power), and expansion of the power grid due to the electrification of many parts of the economy as we phase out fossil fuels. Figure 3 shows examples of these changes from leading forecasters.

> The climate transition is likely to be the greatest transition of our economy since the industrial revolution.

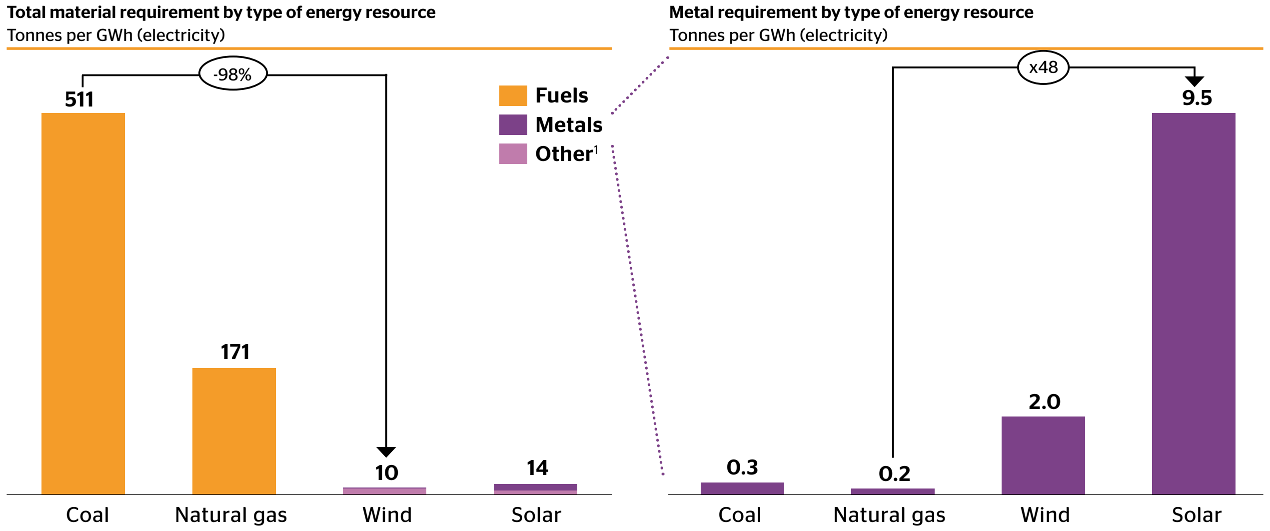
Figure 3. Examples of expected development globally of climate technologies with a great impact on the demand for metals
Substantial growth in electric vehicles, renewable electricity and grid expansion are needed to achieve the climate goals. These products require more metals and new kinds of metals.



Source: IEA ETP 2020 (Sustainable Development Scenario); BNEF Electric Vehicle Outlook 2020

These changes mean an increased need for metals, as the new technologies often require more metals than the old fossil-fuel-based technologies to produce the same result. Figure 4 shows the material and metal intensity of coal, natural gas, wind, and solar production. The transition from coal and natural gas to renewables will substantially reduce the total materials needed, including fuels, metals, and other materials such as concrete, plastic, and glass. Wind power, for example, requires only 2% of the total materials needed per GWh compared to a coal-fired power station. At the same time, however, the need for metals increase 10–50 times to produce the same amount of electricity. Similarly, though less dramatic, the demand for metals in an electric car is higher than a conventional car since the battery and electric motor require sizeable metal quantities. For example, an electric car contains up to four times as much copper as a conventional car (Watari, 2018).

Figure 4. The material and metal intensity of various types of energy resources
The shift from fossil energy to renewables will mean a substantial reduction in the total material requirement for generating electricity, but the need for metals will increase.

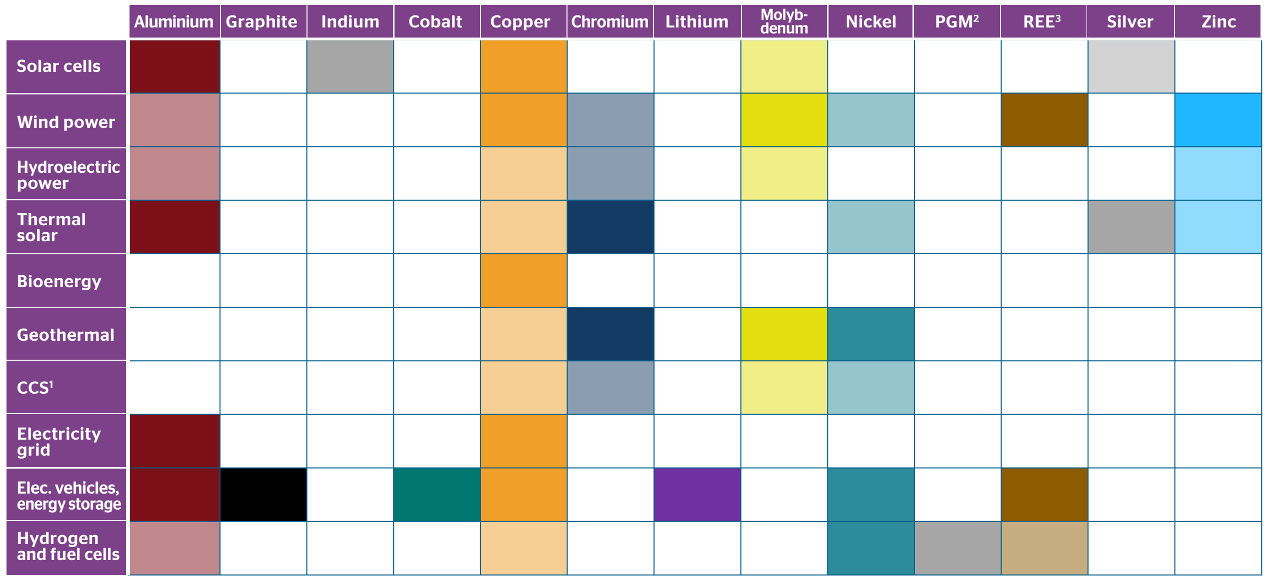


1 Mainly concrete, but also e.g. glass and plastic.
Source: DOE (2015) Quadrennial Technology Review; US Energy Information Administration (2021)

Alongside the increasing use of metals, our society will also need new metals that we previously have not used on a large scale. Figure 5 shows an overview of metals necessary for different technologies (excluding iron). Electric vehicles and batteries are examples of technologies that require many metals that have previously only been used on a small scale. Lithium-ion batteries, which are the leading technology, require – among other things – lithium and cobalt, which have already seen substantial growth in the past ten years (Figure 1). Another example is that electric motors and wind turbines create a greater need for rare earth elements (REEs): neodymium, dysprosium, and

Figure 5. Relative importance of metals for different climate technologies
Some metals have a fairly narrow area of use but can be critical for these technologies. The list is not exhaustive and excludes iron, for example, which is used in more or less all technologies.

The darker the colour, the more important the metal is for the technology



1 Carbon capture and storage.
2 Platinum group metals.
3 Rare earth elements.
Note: Not exhaustive list of metals.

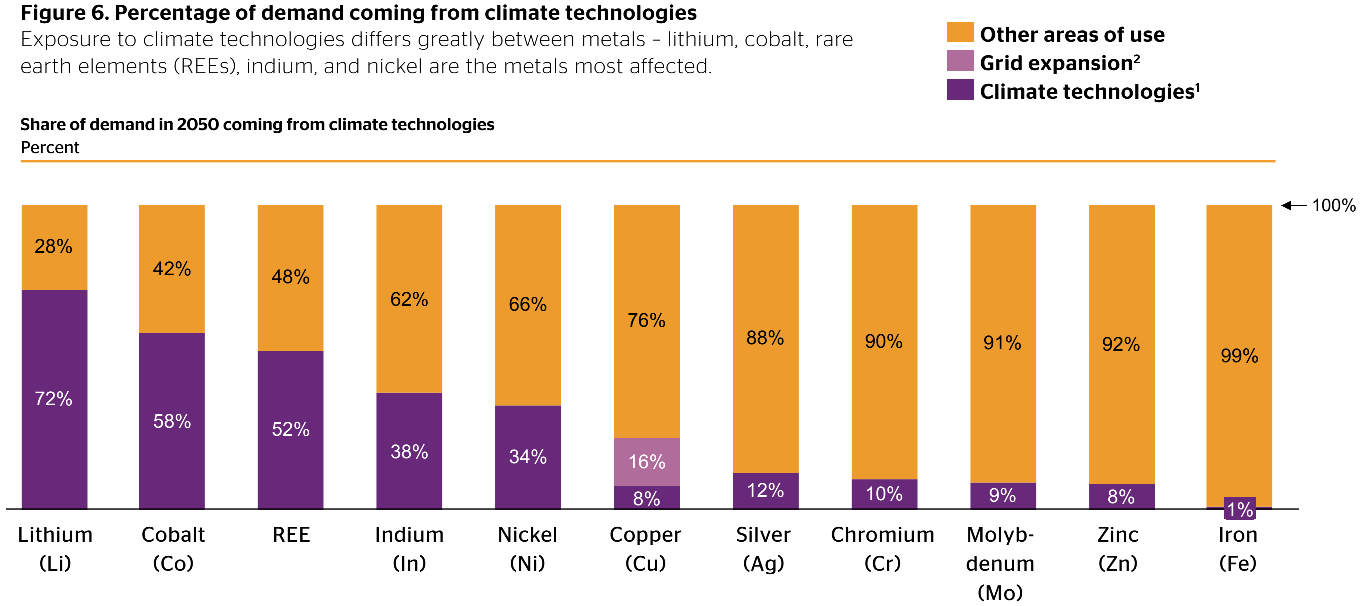
Source: IEA, World Bank

The industry is important to the Sweden climate ambitions through their effort to create climate-neutral value chains. Ambitious investment plans in the industry companies can make Sweden a world leader on climate neutral raw material.

praseodymium. Technological development and the possibility of substituting metals depending on how prices develop means that the demand for specific metals in the future may change. One example is cobalt, where various battery producers are currently looking into alternative metals.

Figure 6 shows the proportion of the demand coming directly from these climate technologies in 2050. These technologies will create important new demand categories for some base metals, such as iron and zinc. However, this will not be their primary driver of demand. Meanwhile, for the energy-critical metals such as lithium, cobalt, neodymium, indium, and nickel, the climate technologies will have a determining influence on demand and will drive significantly increased consumption. In the case of copper, secondary effects of the climate transition have a great impact and are one of the drivers behind the high level of expected growth shown in Figure 1. In large, the climate transition involves switching to electrification in many sectors of society. The power grid will have to expand substantially as cars, heating, and industrial processes become electric. In the case of Sweden, electricity demand expects to more than double in the period up to 2045 (Material Economics, 2021).

Figure 6. Percentage of demand coming from climate technologies
Exposure to climate technologies differs greatly between metals – lithium, cobalt, rare earth elements (REEs), indium, and nickel are the metals most affected.

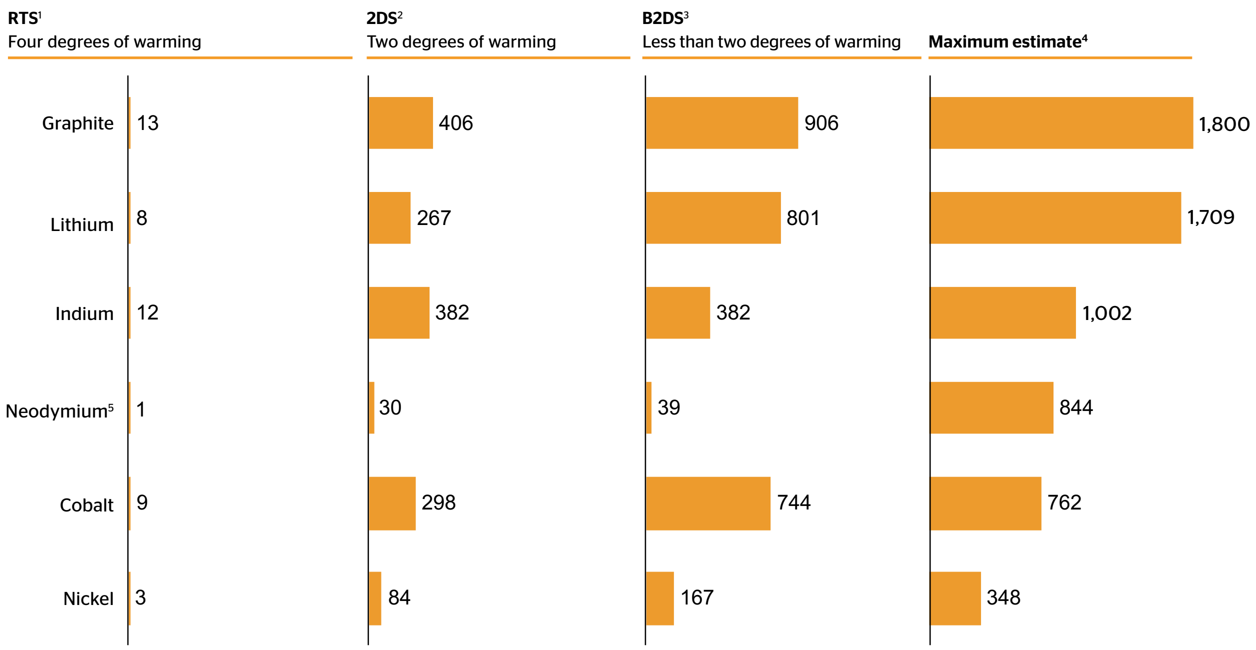


1 Renewable electricity, batteries, electric vehicles.
2 Increased expansion from electrification of fossil applications (transmission, distribution and transformers).
Source: BGS; Watari et al. (2018, 2021); IEA (2021)

It is worth mentioning the relationship between climate ambitions and demand for metals. A higher climate ambition means faster expansion of climate technologies. This expansion, in turn, means that society will need more metals up to 2050 as climate technologies are a significant demand driver for metals. Figure 7 shows the expected demand for several metals and minerals with different scenarios.

Figure 7. Global metal requirement with different scenarios
For metals with great exposure to climate technologies the pace of the climate transition plays a major role in future demand. Higher ambitions mean a significant need for metals.

Expected demand in 2050 relative to 2018 due to climate technologies, by climate scenario
Percent



1 Reference Technology Scenario.
2 2 Degree Scenario.
3 Beyond 2 Degrees Scenario.
4 Maximum estimate from the literature.
5 The World Bank model of neodymium excludes demand from electric cars.
Source: World Bank (2020); IEA ETP (2017); Watari et al. (2020; 2021)

To extract metals requires large amounts of energy, so one might question whether this extraction increases the total emissions of greenhouse gases. However, life cycle analysis shows that the combined emissions from climate technologies, including metal extraction, are significantly lower than today's fossil-based technologies (IEA 2021). One example is electric cars, where life cycle emissions are less than half of the equivalent vehicles with an internal combustion engine, even if the electricity comes partly from fossil fuels. The lower life-cycle emissions are due to the greater efficiency of the electric motor. To further reduce emissions, the most crucial measure is to reduce emissions from electricity production. In contrast, the metals in batteries create a relatively small share of the total emissions (7–13%).

The climate transition will also have other effects on how the metals are extracted and used, which this report does not cover in detail. For example, steelmaking is expected to go through a hydrogen transition while being used in new ways and phased out from fossil products.

Nunasvaara, in Vittangi in the northernmost part of Sweden, holds deposits with one of the highest graphite contents in the world. Graphite is refined and used as the anode in batteries for electric cars. Graphite is not a metal but consists of pure carbon, consisting of a single layer of atoms arranged in a two-dimensional honeycomb structure.

Europe has a greater need for metals than the world around it, given our high ambitions for the climate transition

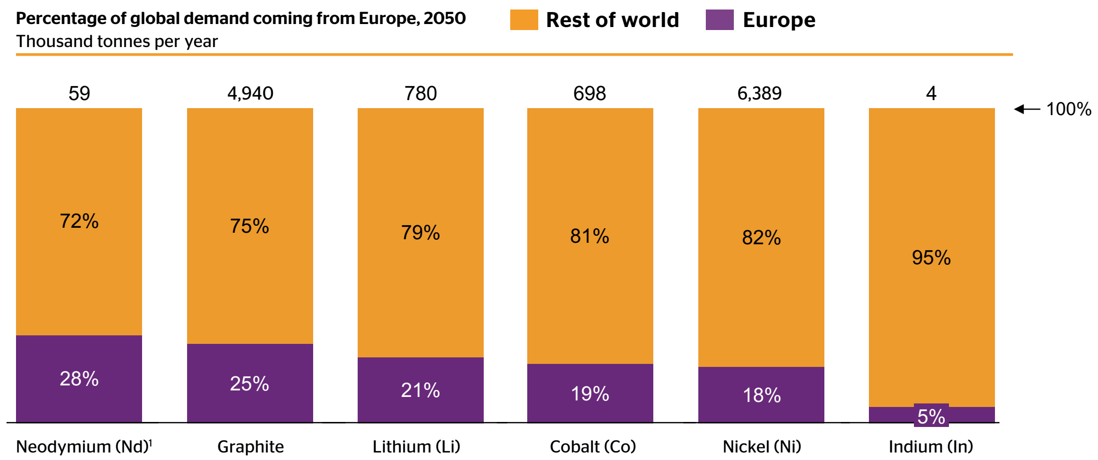
Compared with other parts of the world, the EU has set one of the most ambitious targets for the climate transition. The EU aims to achieve climate neutrality by 2050 and reduce greenhouse gas emissions by 55% by 2030. Moreover, in the EU's long-term budget for 2021–2027, at least 30% of expenditure is earmarked for climate-related projects. This high ambition means that the EU's need for metals for the climate transition will be relatively higher than other parts of the world. Europe is already the largest consumer of electric cars, accounting for 43% of new car sales in 2020[1].

Europe also has other conditions affecting the demand. Globally, solar power is assumed to be the most important energy source in the near future. For northern Europe, however, the conditions are not as good given our geographical position with fewer hours of sunlight. Instead, wind power is expected to play a crucial role. Europe is already a leading producer of wind power and currently produces 89% of all offshore wind energy.

Figure 8 summarises Europe's share of the total demand for several energy-critical metals. Europe's share of the global economy is currently around 15%, but for many of these metals, demand up to 2050 will be significantly greater than that. Neodymium, a rare earth element used for permanent magnets in electric cars and specific wind turbines, will be essential for Europe's transition since Europe make up around 28% of global demand. Indium, a metal used in solar cells, will be comparatively less important in Europe's transformation than other regions.

1. According to EV Volumes 2020

Figure 8. Percentage of global demand coming from Europe in 2050
Europe is expected to have higher demand for some metals than the world around it (relative to its current 15% share of the global economy). The metal mix will also be different, given the greater focus on wind, lesser focus on solar and the relatively fast transition to electric cars.



1 Demand for the rare earth elements dysprosium and praseodymium is also expected to grow substantially.
Source: Analysis by ME based on "European Commission, Critical materials for strategic technologies and sectors in the EU – a foresight study, 2020"; BGS; IEA ETP 2020; Watari et al. (2020)

The transition from coal, oil, and gas to fossil-free electricity is the most important factor in reducing our climate impact and meeting the Paris Agreement. Wind turbines, solar cells, improved electricity networks, batteries, and electric vehicles are critical solutions. Switching to climate-neutral technologies will dramatically increase the need for some specific raw materials – for some, the demand will increase a hundred-fold.

80 percent of all steel is currently recycled.

Recycling is important, but not enough to meet the total demand

Will the supply of metals be enough to meet future demand? There is a finite quantity of metals in the Earth's crust that humans can extract. Therefore, it is sometimes speculated that the world will reach a point of "peak metal", after which the supply of metals from the mining industry will fall. However, most studies suggest that this is far away and will not be relevant for the time horizon in this report (Jowitt et al., 2020). In other words, the mining industry can meet the demand for metals and minerals up to 2050.

Another essential source of metals is from products that have reached their end-of-life. A significant proportion of the iron, copper, aluminium and other base metals used today comes from recycled scrap. Recycling metals has many advantages. Recycling is often more energy-efficient than primary production. In some cases, recycling is cheaper, and it also reduces the amount of material sent to landfills. So can society meet its use of metals solely by recycling what we already have extracted? Unfortunately, this is not possible, although there is potential for improvements compared to today. Figure 9 shows the effects of improved recycling and other circular measures for two metals that will develop in different directions up to 2050.

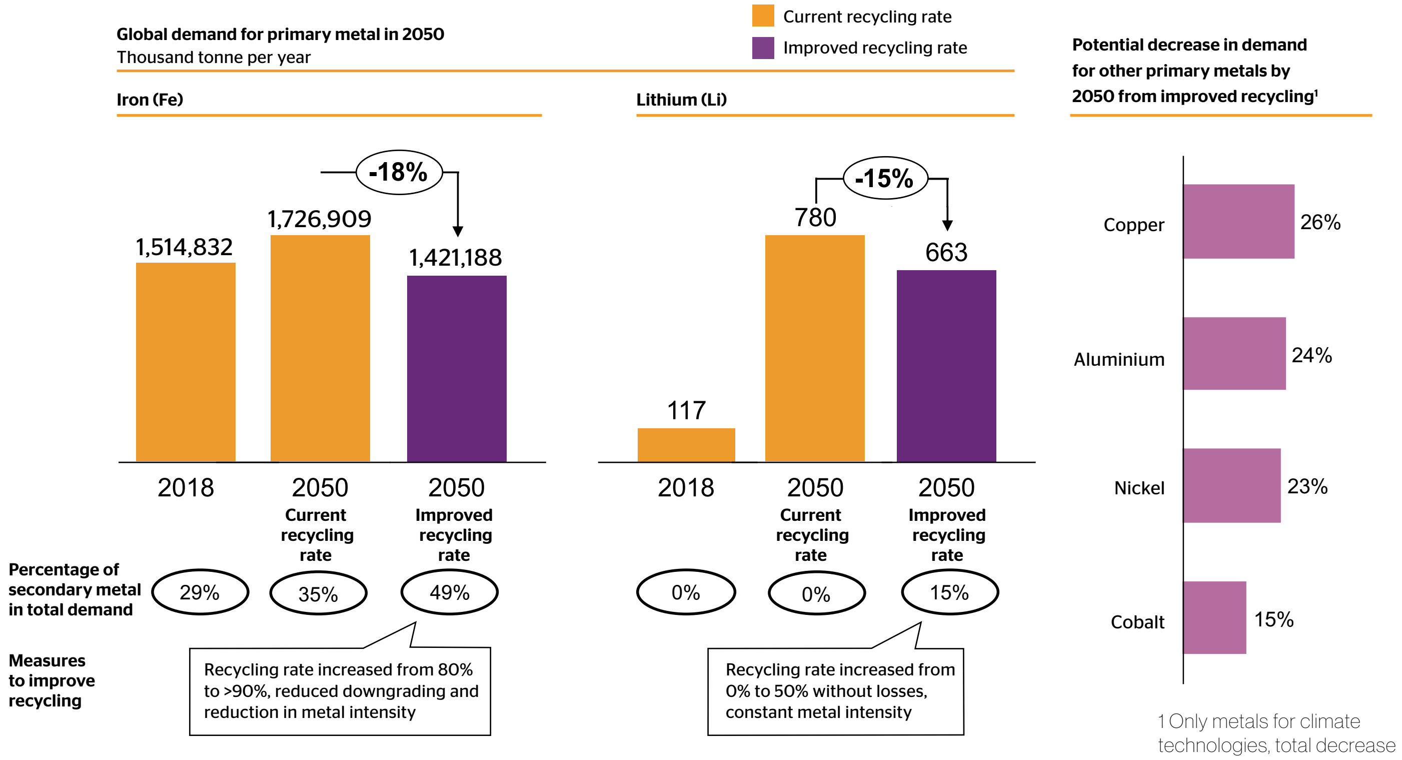
Iron is the metal used most, primarily in the form of steel, in everything from cars to bridges to cutlery. Since this metal is so widespread and has a long history of use, there is a volume of scrap that is recycled into new steel each year. Around 80% of all steel is recycled, but only approximately 29% of all newly produced steel comes from secondary metal (scrap). The difference between these figures is that steel products' useful life is often very long, and the global economy is still going through a phase of increased demand for steel. Suppose the recycling rate remains at 80%, then the proportion of secondary metal will increase to 35% by 2050. Suppose the recycling rate can be improved to more than 90%, while at the same time various other measures are taken to improve recycling. In that case, it will be possible to increase the proportion of secondary metal to 49% by 2050. The improved recycling would mean a decrease in demand for primary metal in 2050 of around 18% compared with the current recycling rate and a 6% decrease compared with today's demand. However, more than half of all the iron needed would still come from mining.

Lithium is a metal with a completely different profile than iron. It is only in recent years that lithium has begun to be used on a larger scale, with the technological breakthrough involving lithium-ion batteries. At present, practically no lithium is recycled at all, and the proportion of secondary metal is therefore also zero. Much research is taking place into recycling lithium-ion batteries, and a lithium-recycling industry is being built. However, the share of lithium that will be recycled by 2050 is very uncertain today. If the recycling rate were to reach 50% without other losses, this would mean that the demand for primary lithium would decrease by around 15% by 2050.

> "Only in recent years has lithium begun to be used on a larger scale.

Figure 9. Effect of increased recycling rate on demand for iron and lithium

Increased recycling can reduce demand for primary metals, but not enough to meet all of the need. It is estimated that improved recycling could reduce the need for primary metals by 15-26% at most in the period up to 2050 relative to the base scenarios.



1 Only metals for climate technologies, total decrease likely to be lower.

Source: World Bank (2020); Watari et al. (2018); Material Economics.

The World Bank (2020) has carried out a similar analysis for four metals (copper, aluminium, nickel, cobalt), and the picture is similar in all cases. Even if the recycling rate can be maximised, demand for primary metals up to 2050 will only decrease by around 15–26%. In this case, the analysis took only metals used for climate technologies into consideration. For most fast-growing metals, this means that demand will still grow substantially compared with today. Increasing the recycling rate is challenging and sometimes requires new technologies and processes for collecting and transforming the scrap to new material. Many metals exist in small quantities along with other metals and other materials, such as plastics. This mix means there are technical and economic challenges associated with increased recycling that need to be solved. While this ought to have a high priority, as it would result in substantial gains for our society, there remains a significant need for continued mining.

"Swedish bedrock is rich in deposits"

Erika Ingvald
Head of Division, Mineral Information and Mining Industry
SGU – Geological Survey of Sweden

Why is Sweden an interesting country in which to look for innovation-critical metals?

– Swedish bedrock is rich in deposits of raw materials that may be of interest to the technologies we need to manage society's development and reduce climate emissions. It is also reasonably underexplored compared with similar bedrock in other parts of the world and worth studying more.

What is SGU doing to increase knowledge of Sweden's mineral deposits?

– SGU is surveying the bedrock by many different methods – geological, geophysical, and geochemical – and one aim of this is to understand better the geology in the areas that are particularly rich in deposits to make it easier to explore in the right place. We build up knowledge of geology and develop new technologies to work with researchers to complete our surveys smarter. We are also taking part in various research projects, some of which are EU financed.

What potential does SGU see for extracting key metals from existing mining waste?

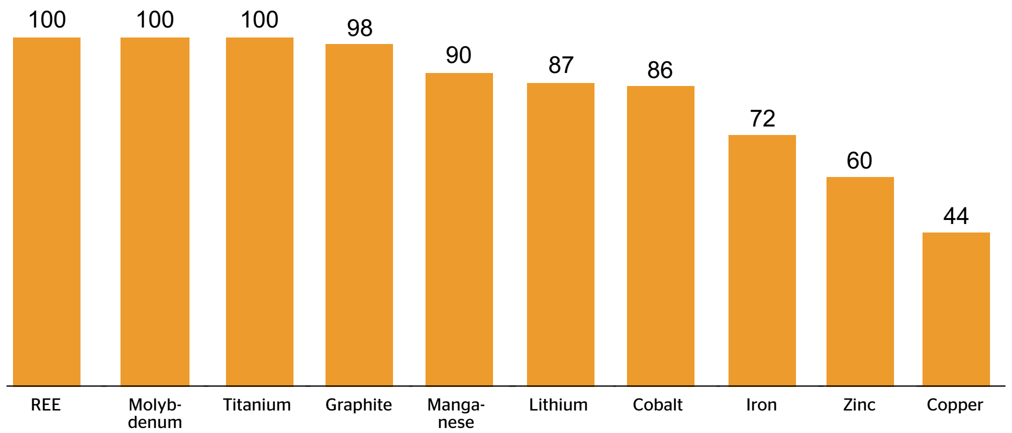
– For several years, SGU has been investigating the potential of historic mining waste. The waste may contain metals that now are important but which were not when we created the waste. In most cases, we are talking about small quantities of waste with varying characters. Therefore in purely technical and economic terms, it may be challenging to use these. In contrast, if we do this in combination with primary extraction, the chances are higher. One example where volumes are large and the waste intends to be used with primary extraction is LKAB's iron ore mines. LKAB is now trying to get profitable techniques to use rare earth metals and phosphorus that work on a larger scale.

Europe is highly dependent on imports of many metals and minerals

As previously described, Europe has a relatively more significant need for metals and minerals for the climate transition than the rest of the world. At the same time, the EU is highly dependent on imports of many metals and minerals. Today, the metal market is fully globalised since metals have a high value relative to the shipping costs. Europe imports many of its metals from Asia, Africa, and South America. Figure 10 shows the import dependency for selected metals. At present, the EU imports 100% of the demand for rare earth elements, molybdenum, titanium, and nearly all of the need for graphite, manganese, lithium, and cobalt – critical metals for such things as electric cars, batteries, and wind turbines. Being heavily dependent on imports is not necessarily a significant problem. However, it reduces supply security and makes it challenging to build up value-chains associated with the metals.

Figure 10. Import dependency for selected metals and minerals
Europe imports most of the metals we use, and for some metals the EU is entirely dependent on imports.

Import dependency of EU sourcing by metal (selected metals)
Percent

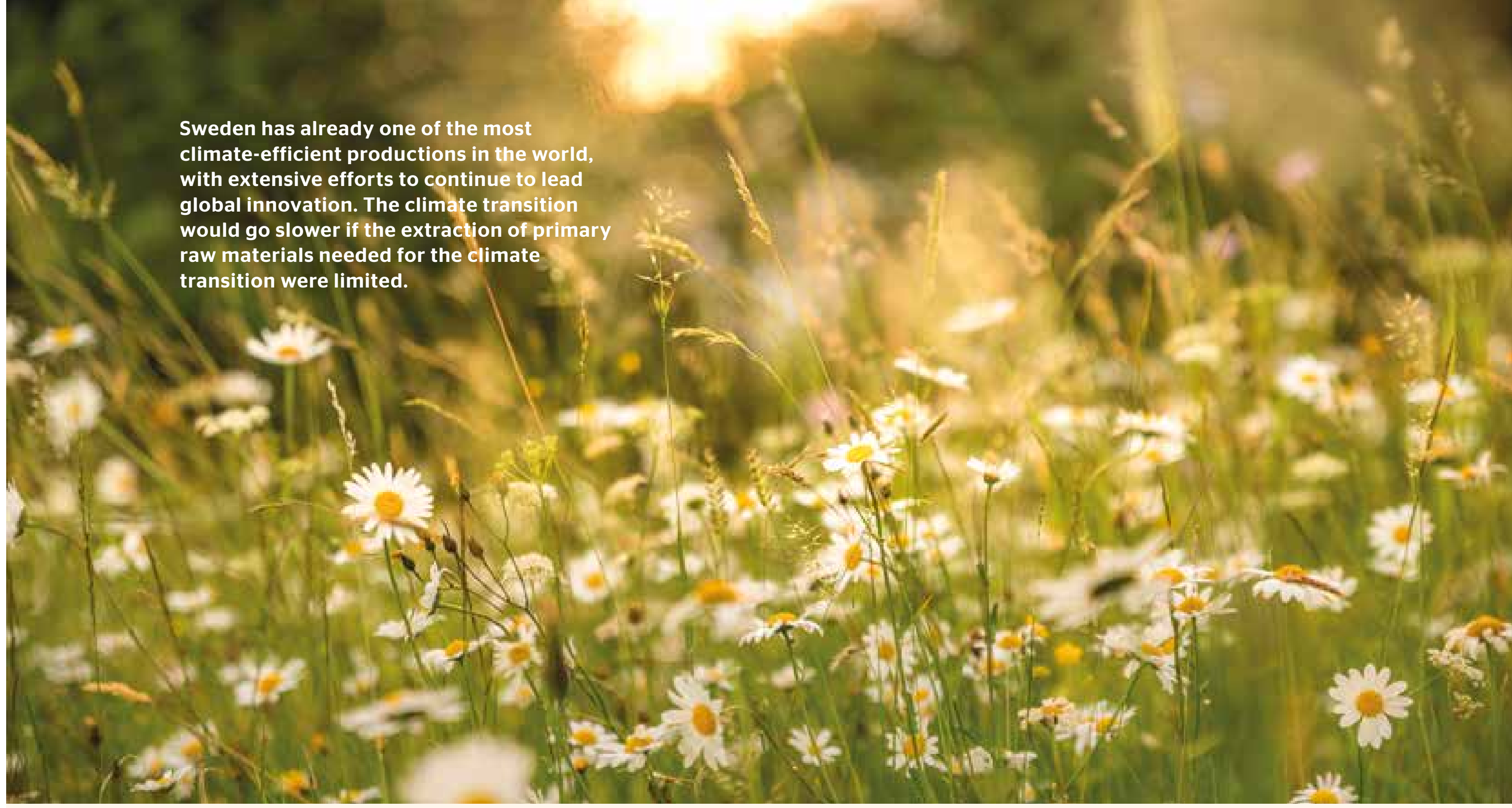


Note: Import dependency (import reliance) for extraction stage (not processing/refining)
Source: Study on the EU's list of Critical Raw Materials (2020)

The lower supply security means a greater risk of restrictions on supply, whether intentional or unintended. In recent years the world has seen various examples of how the dependence of individual countries or regions has hurt world trade. Examples include the shortages of goods from China at the start of the Covid pandemic, export bans on vaccines, a shortage of semiconductors from Asia and logistics disruption due to blockage of the Suez Canal. This dependency is particularly noticeable for those metals where a large proportion of the supply comes from one or a few countries. One example is rare earth elements, for which more than 60% of world production comes from China (USGS, 2020). There are also examples of how China has used its unique position regarding rare earth metals for foreign policy purposes. Building up domestic production is one way of improving the security of supply.

Another advantage of domestic production of metals and minerals is the potential value-chains associated with the products. For example, the possibilities for building up a more substantial value chain in Sweden around the manufacture of lithium-ion batteries has been highlighted (Tillväxtanalys, 2017). The extraction of graphite, lithium, and cobalt could be vertically integrated, potentially lowering the production costs. Another advantage of domestic production is that it increases opportunities to observe and influence the environmental impact of the extraction.

Building up a certain proportion of domestic production within the EU could increase supply security and favour opportunities to construct a strong industry around climate-technology value chains.



Sweden has already one of the most climate-efficient productions in the world, with extensive efforts to continue to lead global innovation. The climate transition would go slower if the extraction of primary raw materials needed for the climate transition were limited.

"We welcome challenging environmental requirements"

Pia Lindström
HR and Sustainability Director
Boliden Mines

What does increased electrification in the world mean for Boliden as a metal producer?

– Our metals such as copper and nickel are essential for the climate transition, and in purely concrete terms, it means that Boliden will become a key player in Europe's climate transition. The transition of energy production and greater electrification implies that the demand for many base metals will significantly increase. Quite simply, we have the future ahead of us, and our focus is on producing these metals in the best possible ways.

What does Boliden's "low-carbon copper" initiative mean?

– We have set a goal to reduce our climate impact by 40% in the period up to 2030, from an already world-leading position. Through low-carbon copper, we want to make it possible for others to choose climate-efficient copper so that our customers can reduce their climate impact, too, rather than importing copper from countries where both the environmental impact and the climate impact are much higher. We are pleased with the interest that this initiative has generated.

What are your biggest sustainability challenges, and how are you dealing with these?

– Our biggest challenge is access to land from a long-term perspective. For mining operations, you need land for production and sustainable waste management. Additionally, this needs to be planned over a long period. The challenge links to how the environmental permit processes are currently conducted in Sweden. We welcome challenging ecological requirements, and we invest considerable resources and ambitions in minimising the environmental impact in all phases of the operations. All sustainability aspects are becoming increasingly important to society, and rightly so, and it is of the highest importance that we can meet these expectations and requirements to operate. Unfortunately, at the moment, the processes surrounding these environmental permits are entirely unpredictable – which means there is a risk that our already high dependence on imports of metals will become even higher, at the expense of more significant environmental impact elsewhere. Combining strict environmental requirements with an overall perspective in these processes is key – not just for us, but for the whole of our industry.

90

percent of EU iron production comes from Sweden.

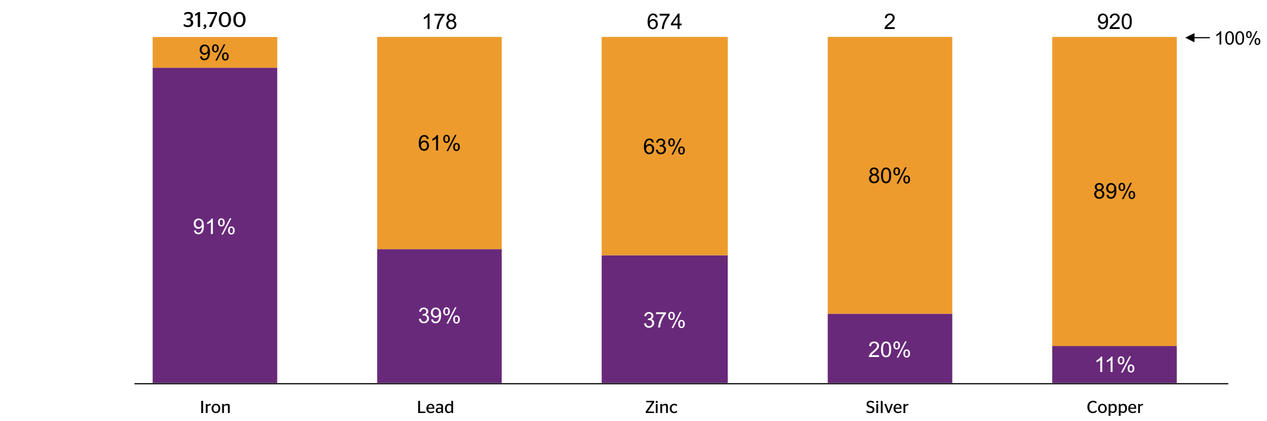
Implications for Sweden: the Swedish mining industry has an important role in the transition to a sustainable society

Sweden has a long history of mining and metal refining stretching back more than a thousand years. Today, Sweden is a leading mining producer in a global metal market, and the country is a critical part EU's supply of metals such as iron, zinc, copper and lead (Figure 11). Sweden accounts for more than 90% of the EU's production of iron and more than a third of the region's production of lead and zinc.

Over the years, Sweden has developed an internationally leading business, in which not only mining companies are at the forefront. Sweden has also built industries around the mines, such as world-leading technology companies specialising in mining equipment and engineering. In addition, there is significant production of industrial minerals that, in some cases, is directly linked to the production of metals.

Figure 11. Swedish metal production in relation to other EU countries
Sweden has an important mining industry and accounts for a significant proportion of EU metal production.

Sweden's share of EU production of selected metals in 2019
Percentage of total production (thousand tonne)



Source: SGU – Geological Survey of Sweden (2019)

"Swedish graphite is unique in the world"

Per-Erik Lindvall
Chair of European Board of Directors Talga Group Ltd

Why has Talga decided to carry out explorations in Sweden?

– Sweden has very interesting geology with good conditions for finding important minerals in minable quantities. Swedish graphite is unique in the world as an efficient input material in batteries. Sweden is also a modern mining and industrial country with high ambitions to be at the forefront of implementing new climate-friendly technologies.

How can Talga's graphite project contribute to the climate transition?

– Talga's graphite, made with renewable energy, will be the greenest globally and has a 96% lower CO2 impact than the battery graphite that currently dominates the market. If you add both the fact that graphite makes up around 40% of a battery and that we need to roll out electric cars to get rid of our fossil dependence, then it's a given.

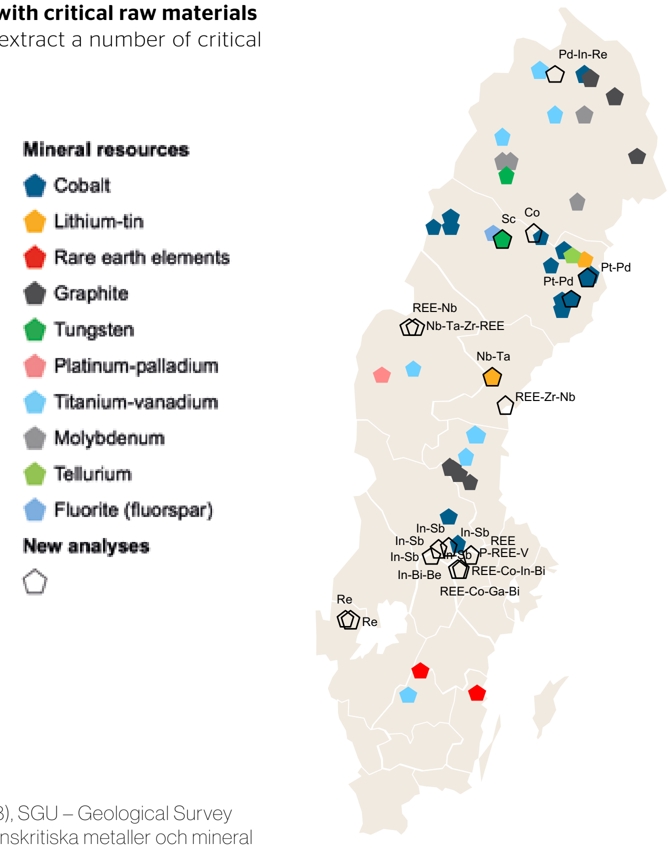
What is your timescale – when can production start?

– Like many others, Talga is waiting on getting all the permits in place. In parallel with this, product qualification jobs are currently being carried out in close cooperation with future customers. The plan is to operate the mine in 2023 and the electric vehicle anode plant in 2024.

There is potential to extract more metals and larger quantities of metals in Sweden, and several projects are in progress. In addition to expanding production of the metals already mined today, there is potential for metals such as graphite, rare earth elements, nickel, cobalt, and lithium. Figure 12 shows the ore-reserve estimated deposits in Sweden, where critical raw materials have been found. There are likely to be more deposits, and the potential is considerable, but more exploration is required to determine the economic value in many cases. One example of a project that has come a long way and will soon become a reality is the extraction of graphite in Vittangi, which would become the largest graphite mine outside China (DI, 2021). It would provide for a fifth of the estimated demand in Europe up to 2025 if the mining can start according to plan. Rare earth elements could also be extracted in Sweden, and there are a number of active projects. One is LKAB's ReeMAP project, which could produce up to 30% of the EU's requirements. Another is Norra Kärr, which is one of Europe's largest known deposits of what are known as heavy rare earth elements.[2]

> The extraction of graphite in Vittangi would be the largest graphite mine outside China.

Figure 12. Deposits in Sweden with critical raw materials
There is geological potential to extract a number of critical metals and minerals in Sweden.



Source: Hallberg & Reginiussen (2018), SGU – Geological Survey of Sweden, Kartläggning av innovationskritiska metaller och mineral

There are various reasons why Sweden is an excellent country to produce metals – low climate footprint, high environmental requirements, and good social circumstances. Swedish mining has significantly lower emissions of greenhouse gases than other parts of the world. In the report "Klimatnyttan av svensk export", the climate benefit generated by Swedish exports of metals from the mining industry is estimated at around 5.6 million tonnes of CO2 (Figure 13). This climate benefit dep ends on various things, including more efficient processes, cleaner electricity, and better ore quality. For example, Boliden produces copper with a carbon footprint of less than a third of the world average (Boliden's green copper has a footprint of less than 1.5 kg CO2e per kg copper, compared with 4.6 globally). The industry also has further improvements planned that will increase the climate benefit to around 30 million tonnes of CO2 by 2040, with the greatest effect coming from LKAB's fossil-free sponge iron initiative.

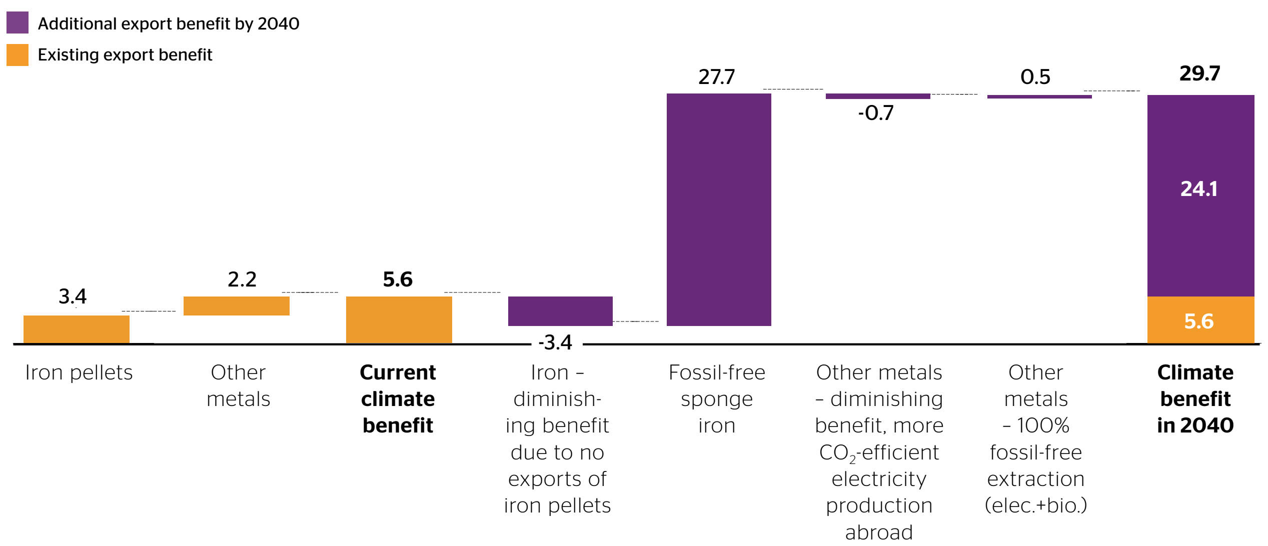
2 Rare earth elements (often abbreviated to REE) are a group of 17 metallic elements that are often split into two subgroups – light and heavy.

Figure 13. Estimated climate benefit of exports of metals from Swedish mining

Swedish mining has a smaller climate footprint than foreign production of metals and through its exports generates a climate benefit corresponding to 5.6 million tonnes of CO_2 (2018).

Climate benefit of Swedish exports of metals from mining

Million tonnes CO_2, 2018 & 2040 (based on current export volume)



Source:Analysis by Material Economics, based on LKAB (2019) – Annual report 2018; LKAB (2020) – Leading the way to decarbonisation; Boliden (2020) – Annual report; SCB (2020) – Varuexport, bortfallsjusterad; Statistics Sweden (2020) – Basfakta för verksamhetsnivå enligt Företagens ekonomi; Svemin (2019) – Färdplan för en konkurrenskraftig och fossilfri gruv- och mineralnäring; IEA (2017) Energy Technology Perspectives; Material Economics (2019) – Industrial Transformation 2050; Milford et. al. (2012) – The last blast furnace

> Sweden has a great opportunity to contribute to climate transition via essential metals.

Sweden also has very high requirements of other environmental aspects and social conditions surrounding mining, which differs substantially from many countries that currently produce energy-critical metals. A life cycle analysis comparing the various environmental effects of extracting rare earth elements in Sweden and China shows that Swedish production would have a fifth of the ecological impacts of the Chinese output (Schreiber et al., 2016). The working conditions and work environment in Sweden are also of an internationally high standard. This can be compared with cobalt extraction, which primarily takes place in Congo, with many reports of child labour and widespread environmental damage in neighbouring villages (Banza Lubaba Nkulu et al., 2018; Aftonbladet, 2018).

In summary, Sweden has a great opportunity to contribute to the climate transition via essential metals produced responsibly. At the same time, Sweden can further develop an important industry and enable new value-chains associated with new climate technologies.

Sweden could potentially mine more than half of the elements on the EU's list of critical raw materials. With this comes a special responsibility. We cannot continue to drive our climate transition with the help of metals and minerals mined from undemocratic states with low environmental requirements.

"The Swedish bedrock is underexplored"

Christina Wanhainen
Professor of Ore Geology
Luleå University of Technology

Why is it important to compile a factual basis concerning the demand for metals and minerals?

– Right now, we live in a technology-intensive world in which sustainability and green transition are buzzwords. It is crucial that all end-users of metals and minerals – not least our decision-makers – understand the future demand. End-users need to understand the link between our consumption of metals, the processes for producing these metals from the Earth's crust, and the consequences of these processes from a global perspective. With the facts in hand, it becomes clear that we need to work on many tracks in parallel to satisfy our requirements – for example, through both recycling and exploration.

What research is currently taking place in Sweden's mineral deposits?

– Research is being conducted on a broad front. However, something that concerns me is that there has been a shift away from ore-genetic studies to studies that focus on benefits or new technologies. Examples of this are the extraction of by-products or the use of new technology within exploration, which can be linked to poorer financing opportunities for projects with a low technology readiness level or TRL. There is an inherent risk in this from a long-term perspective. Experience shows a constant need to review and improve geological models to identify new target areas, such as areas with strategic metals. Successes in the Garpenberg and Aitik areas, for example, are based on new technologies combined with continued review of ore genetic models that increase the understanding of the ore distribution in the Earth's crust.

What are knowledge gaps preventing Sweden from extracting metals that we do not currently produce?

– We are aware of hundreds of interesting deposits in Sweden, where other mining than base metals, iron, and gold could be possible in the future. However, no major scientific investigations have been carried out on most of these deposits in modern times. We, therefore, do not know what type of ores these are, which makes it difficult to estimate how deep they go and whether they can be concentrated and upgraded in an economically, environmentally, and socially sustainable way. Swedish bedrock is remarkably underexplored; we do not know the potential deposits of large areas. If we build up a more detailed understanding of our known deposits and our bedrock, we can draw more certain conclusions about our potential for the domestic production of new metals.

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