An interactive presentation

by Christopher Schrader

As part of the Humboldt Residency Programme 2023 on the topic of „Our Precious Resources"

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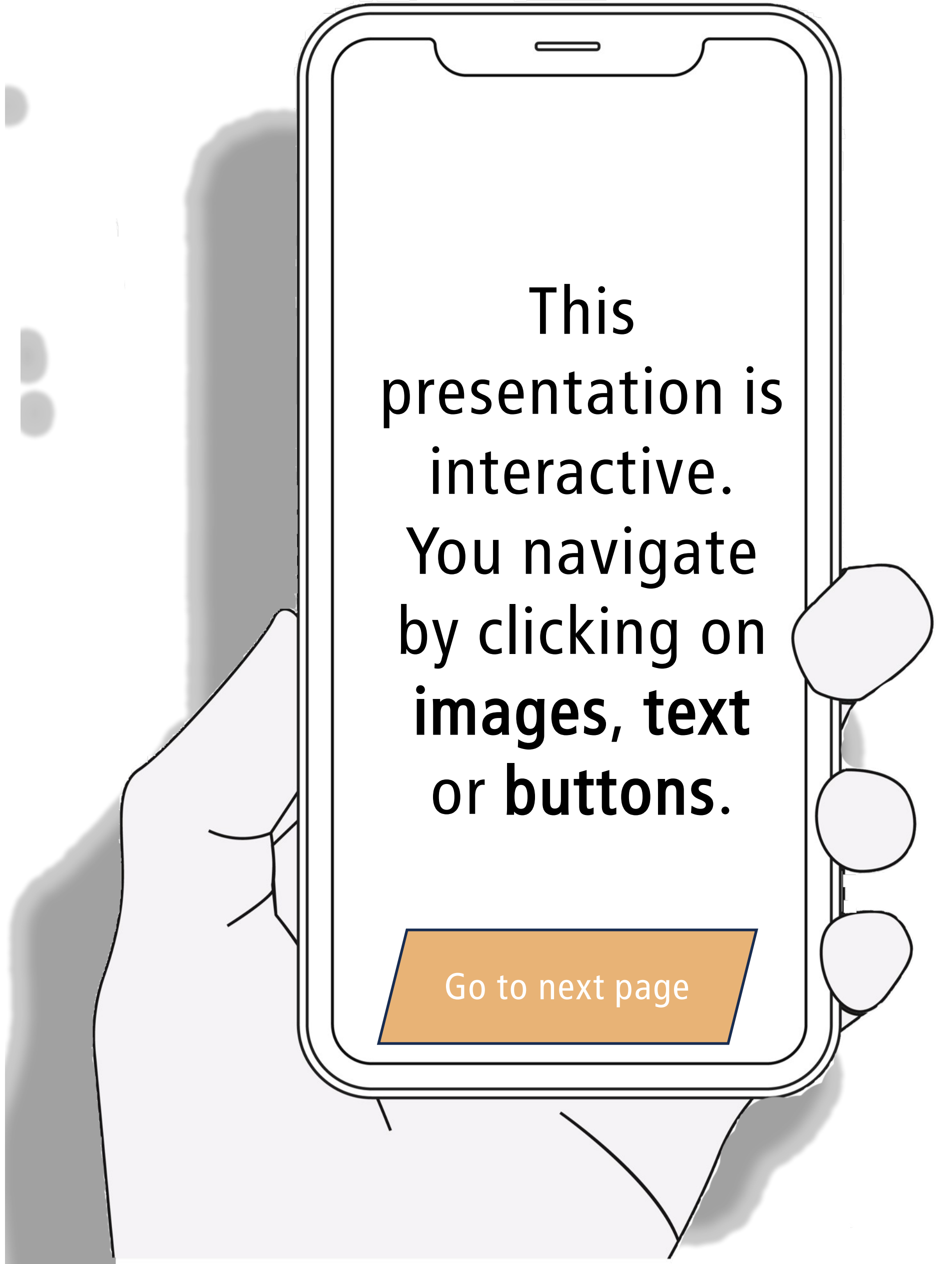
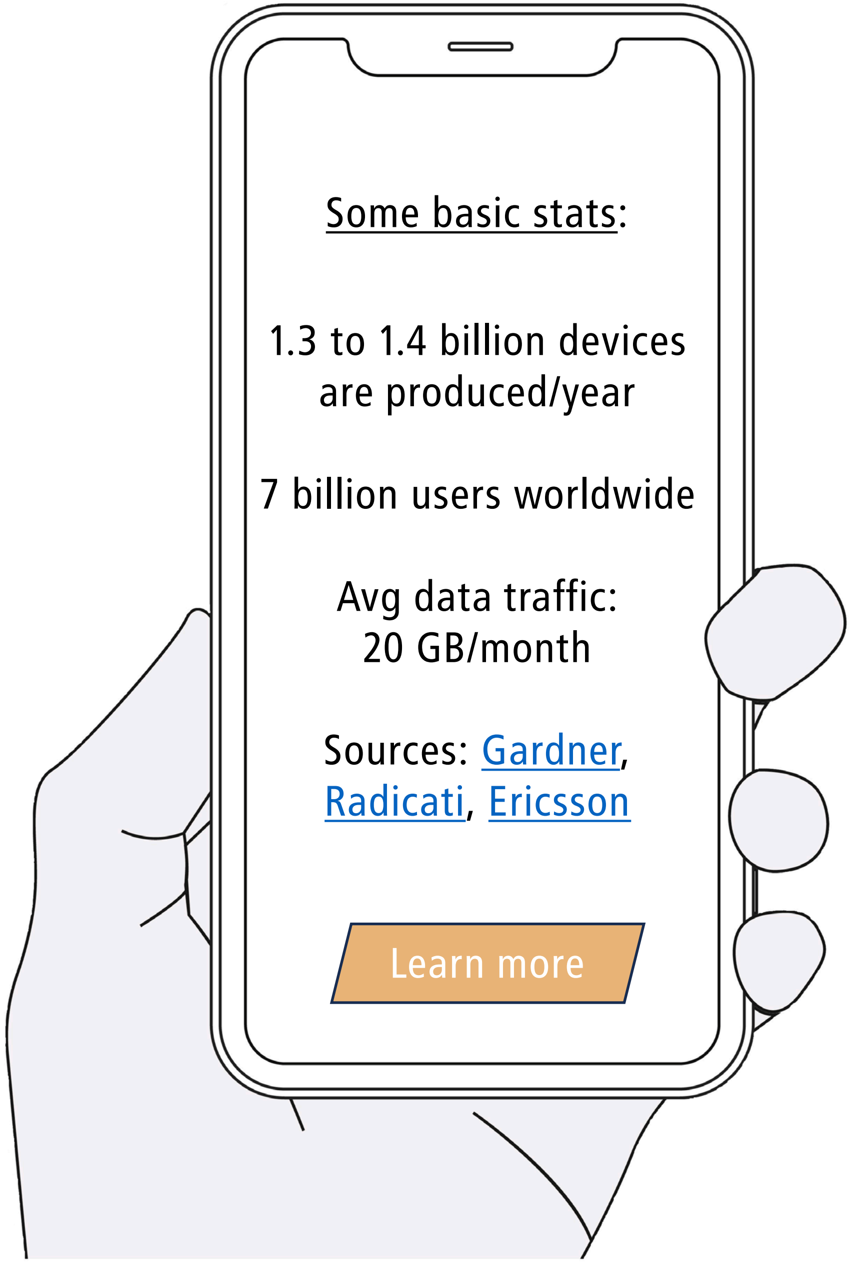
Things invisible to our eye can still throw shadows.



That’s why in this presentation, we are looking at the shadows of invisible resource use in smartphones.

Let's start with some interesting stats and graphs…



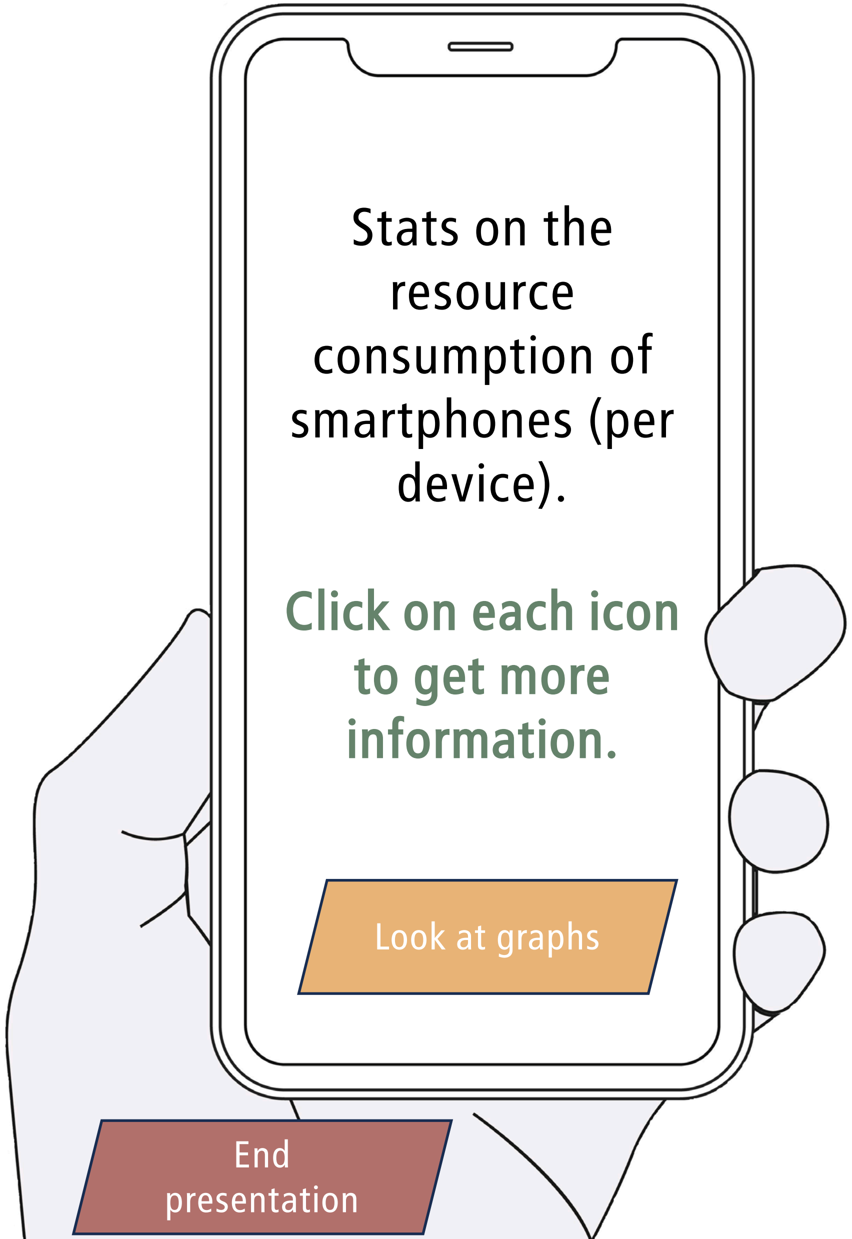
Look at graphs

Transport
260,000 km

(all materials, crude estimate)

Earth moved
Up to 138 kg

Land used
18 m^2



CO_{2eq} emitted
Up to 152 kg

(production and usage for 2 years)

Energy used
Up to 190 kWh

(production and usage for 2 years)

Water used
12,700 l

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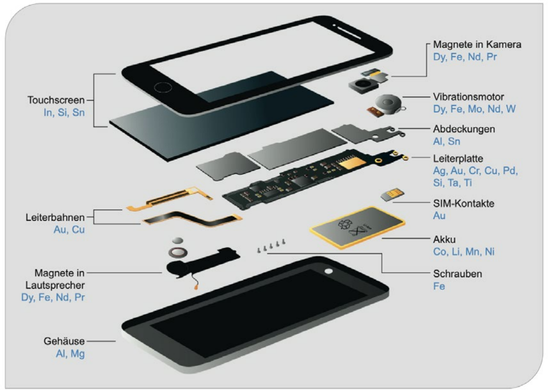
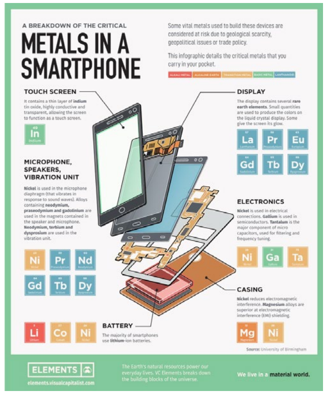
Material Components



Zerlegtes Smartphone und darin vorkommende Metalle (© BGR/PrinzMayer)



Origins

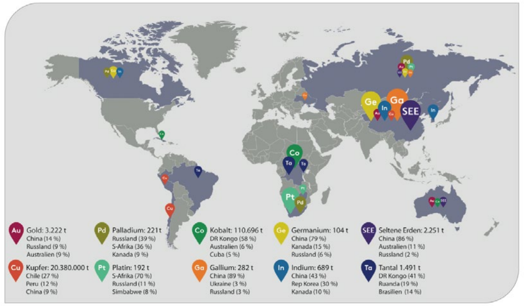
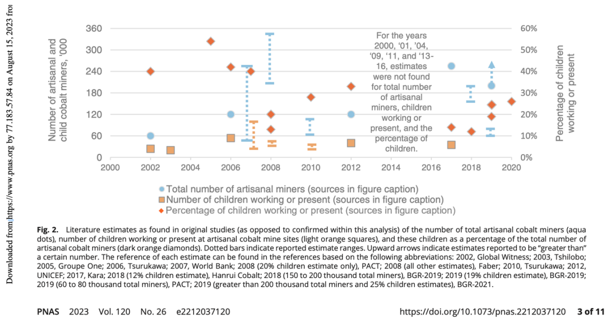
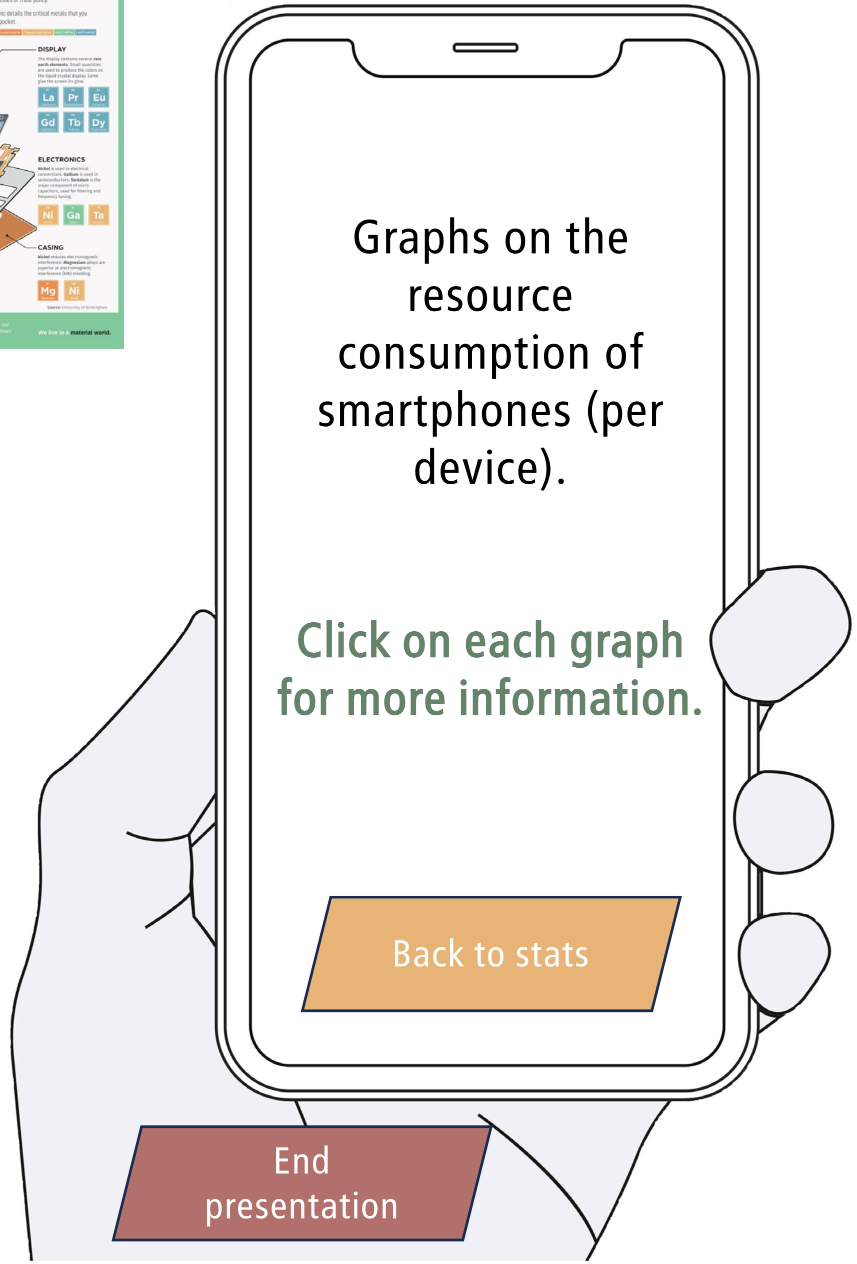


Abb. 5: Top 3 Abbauländer (Bergbauproduktionsdaten 2016) ausgewählter Metallrohstoffe, in Klammern prozentualer Anteil an Gesamtproduktion (© BGR/PrinzMayer).

Child labor in cobalt mines





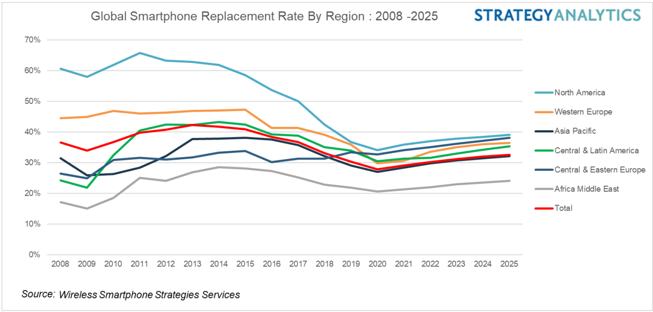
Graphs on the resource consumption of smartphones (per device).

Click on each graph for more information.

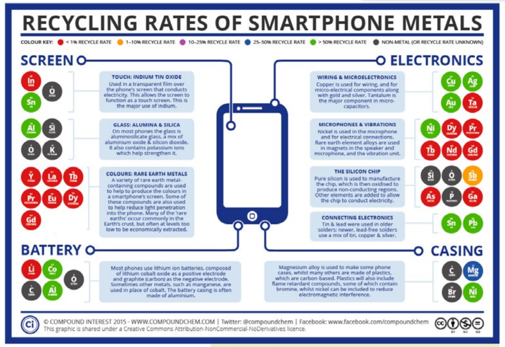
Back to stats

End presentation

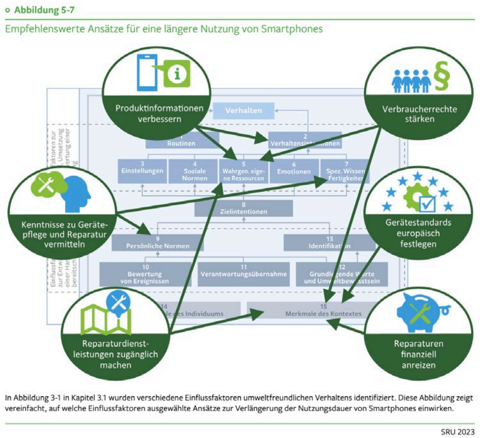
Replacement cycles



Recycling rates



Behavioral change & choice architecture

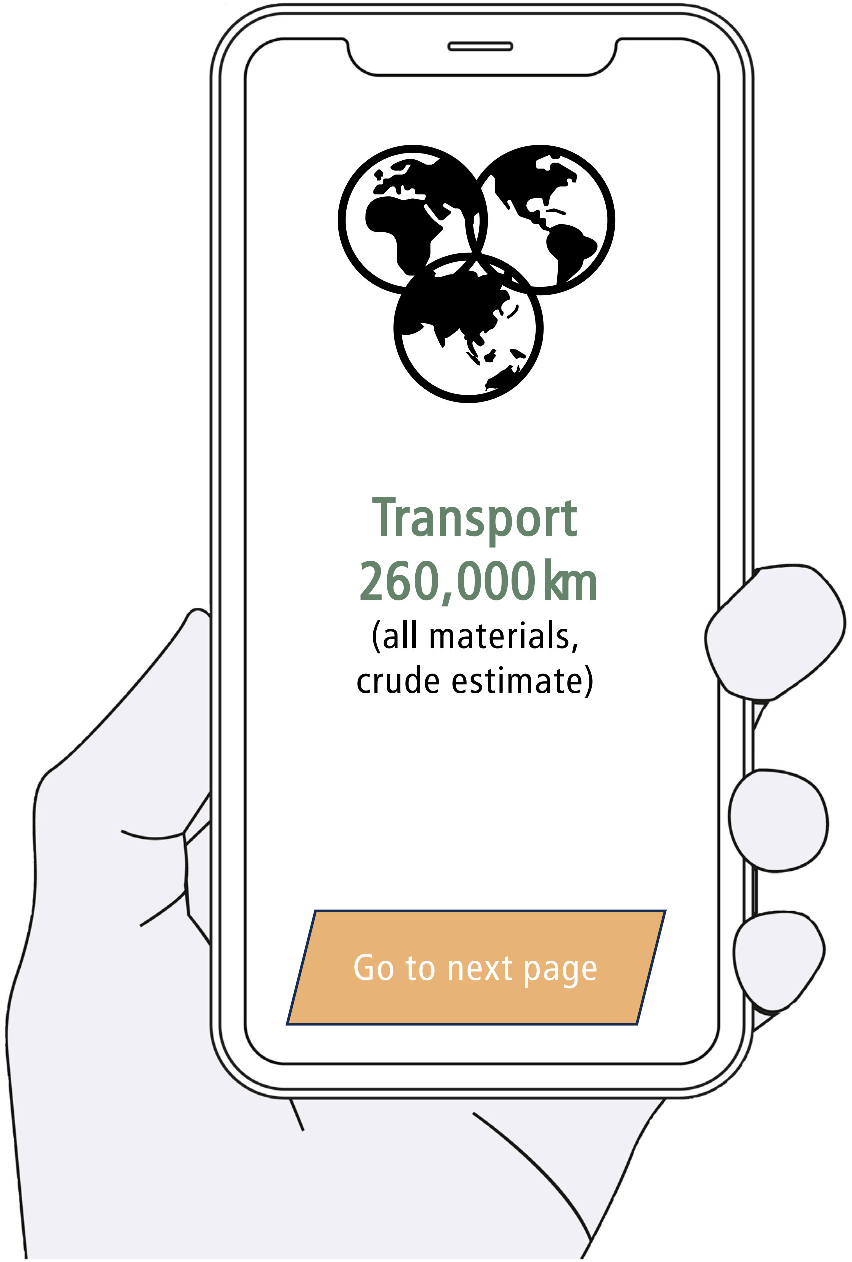


260,000 km is more than six times around the world.

The materials and resources used to build a smartphone come from all around the world. They are mainly dug up in mines, then the ore is refined to metals or metal oxide.

Those are shipped to specialized plants that make components and assemble the device. The transport distance calculated gives a hint at how far this network stretches out.

Look at a map



How is the number 260,000 calculated?

This is a crude approximation – a back of the envelope calculation.

The assumptions are that metals are sent from the capital or main port in their primary source country directly to e. g. Shenzhen in southern China where they are assembled. Then the device is shipped to e. g. Rotterdam for the European market.

This leaves out components assembly in other parts of the world, plus the sourcing of things like glass or packaging.

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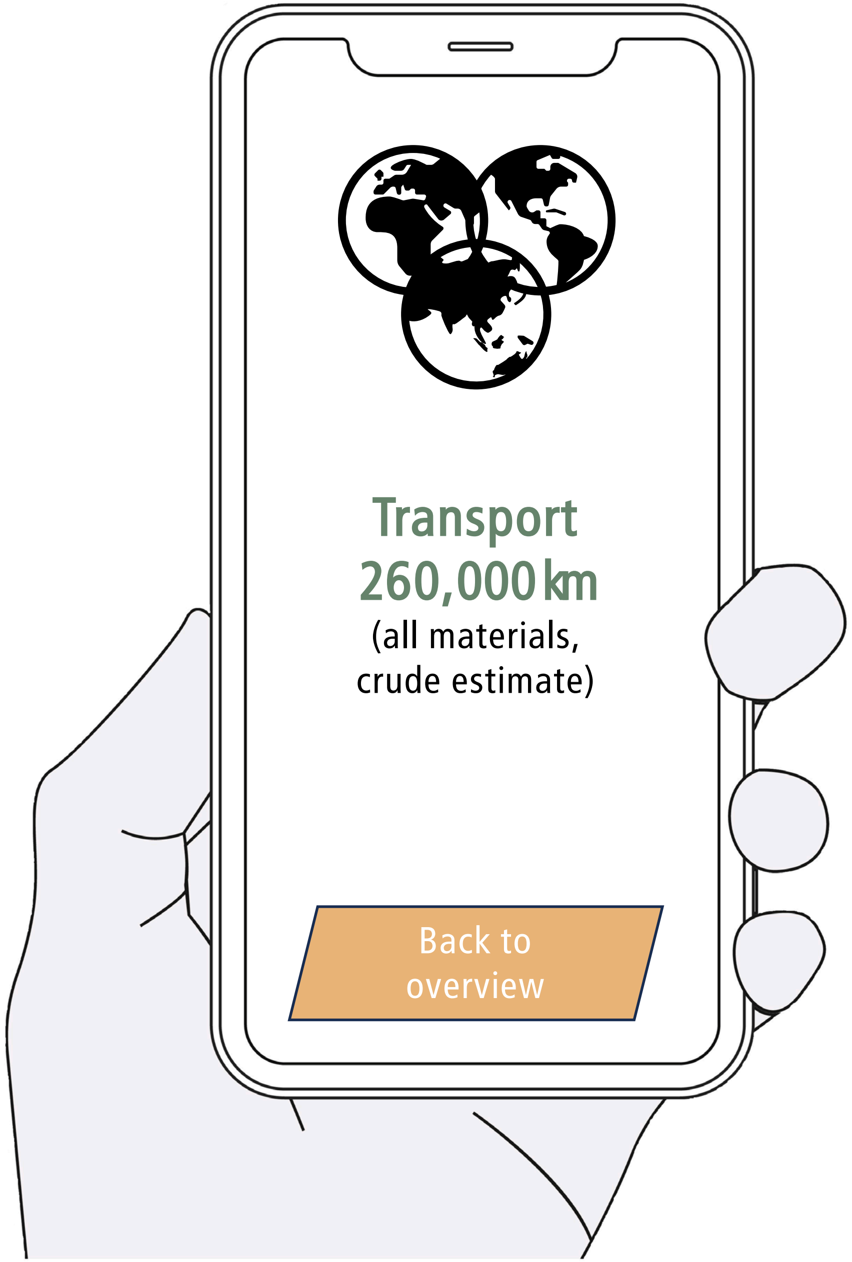
What more is there to know?

If we do the same calculation not only with the countries the resources themselves are extracted from, but trace along multi-step delivery chains, the distance goes up by about **60,000 km**.

And it goes down by the same amount of 60,000 km if we assume that eight metals would be **completely sourced from recycling** old smartphones, among those metals are gold and palladium. Some attempts at realizing this are already under way.

What can be done?

Generally, moving assembly closer to the sources of materials would drastically bring down the distance calculated. This could be done by bringing factories to source countries e. g. in Africa or to places where recycling happens.



Sources

Metal content of smartphones:

- Bookhagen et al, 2020, https://doi.org/10.1016/j.resourpol.2020.101750

Source countries of metals:

- BGS: World Mineral Production 2017–2021, https://www2.bgs.ac.uk/mineralsuk/statistics/worldStatistics.html

Transport distances:

- https://www.routescanner.com/

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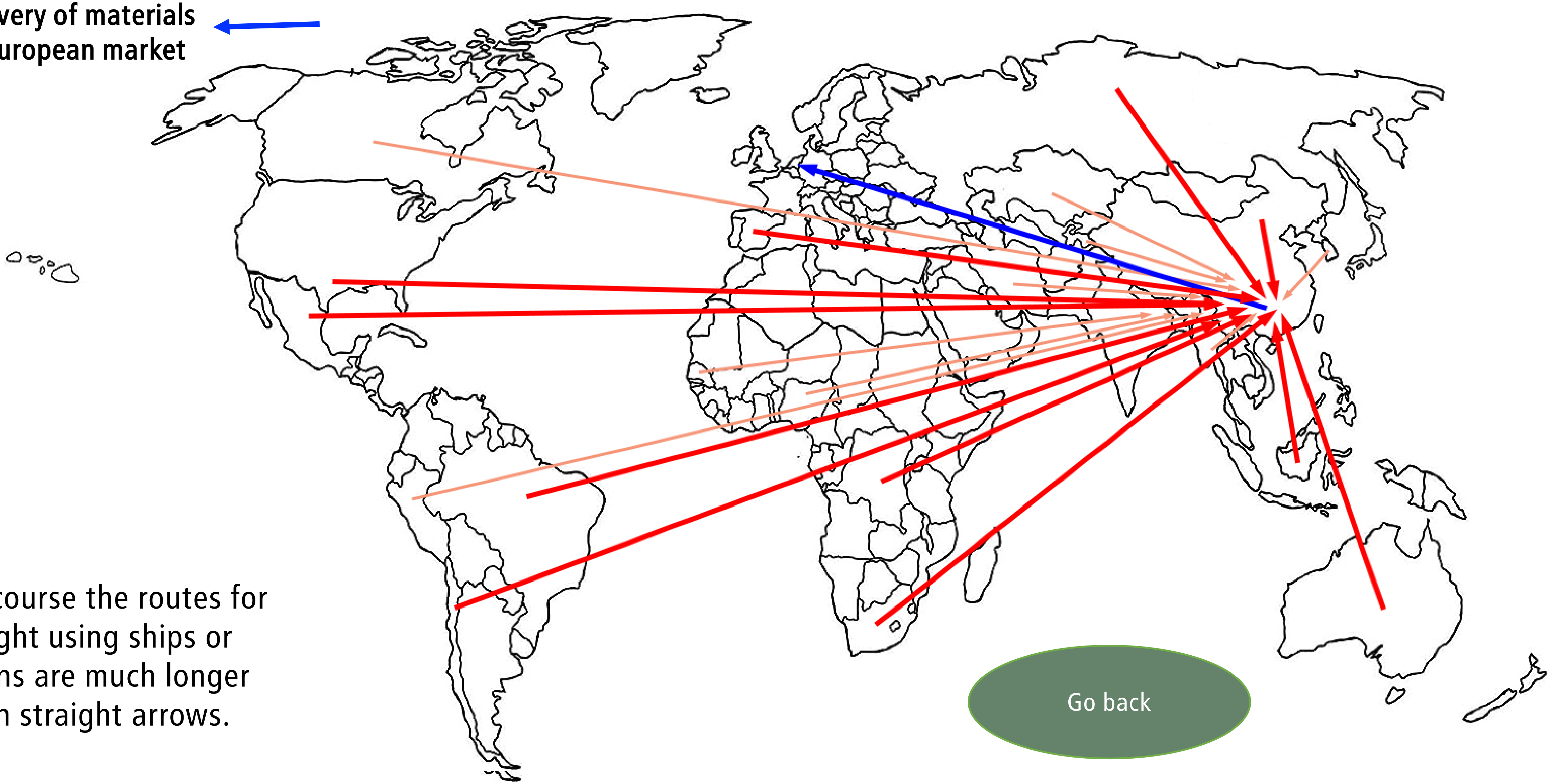
Suppliers of metals and materials

- Primary
- Secondary

Delivery of materials to European market



Of course the routes for freight using ships or trains are much longer than straight arrows.

What does this mean?

A smartphone weighs about 110 to 180 grams. The metal inside it makes up slightly less than half of that coming to 50 to 80 grams.

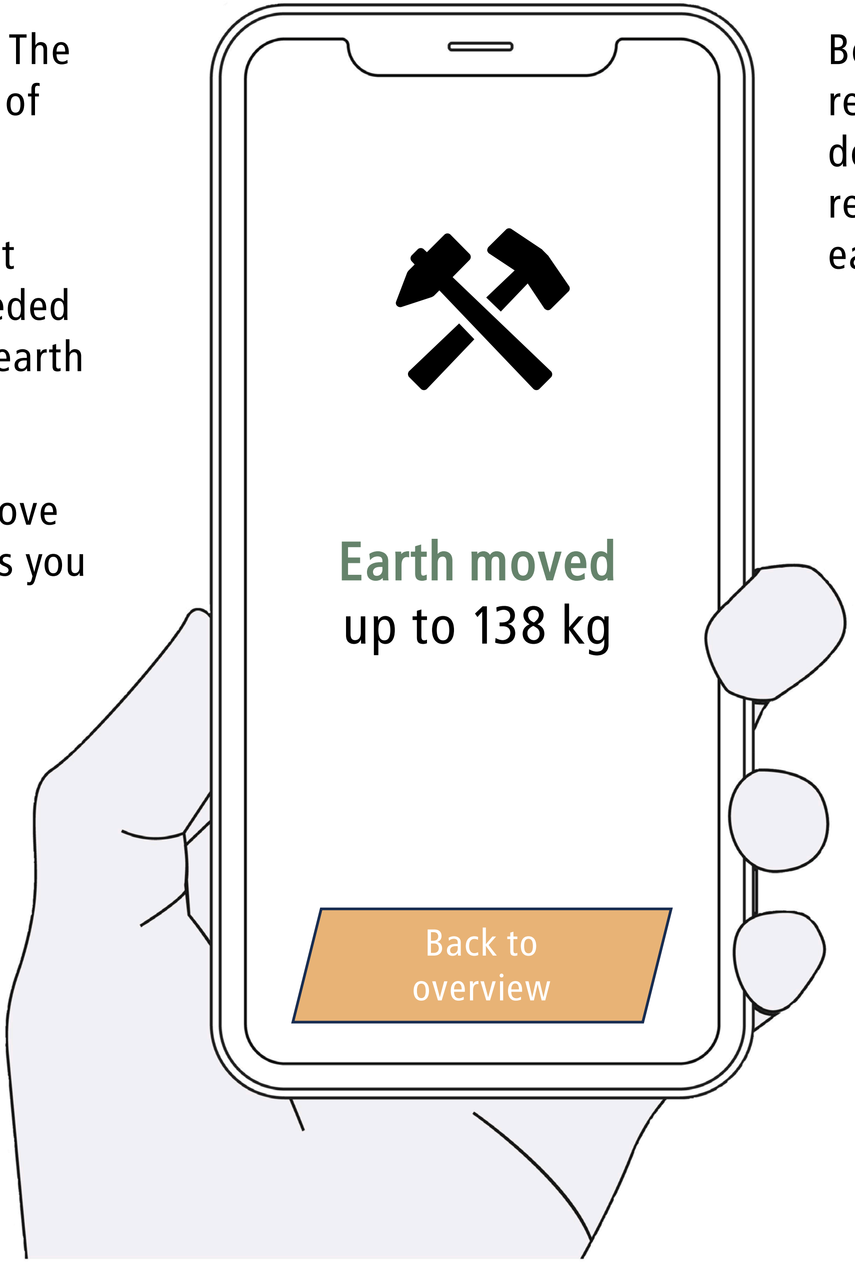
A study assuming a model of 110 g total weight estimates that 138 kg of low-grade ore are needed to produce the metals (not even counting the earth moved from the top of the vein with the ores).

That is a **factor of almost 3000**. You have to move 3000 times as much weight in low-grade ore as you need in metals.

What more is there to know?

Just three metals and one metal group usually make for 90% of the low-grade ore needed: gold, palladium, platinum and the rare earths.

Because they are expensive, the mining of low-grade ore still is profitable.



What can be done?

Being more diligent and investing in recycling methods for metals from devices like the smartphone. Every gram recycled can mean that at least 3 kg of earth and ore remain unmoved.

Source
Metal content of smartphones:
Bookhagen et al, 2020, https://doi.org/10.1016/j.resourpol.2020.101750

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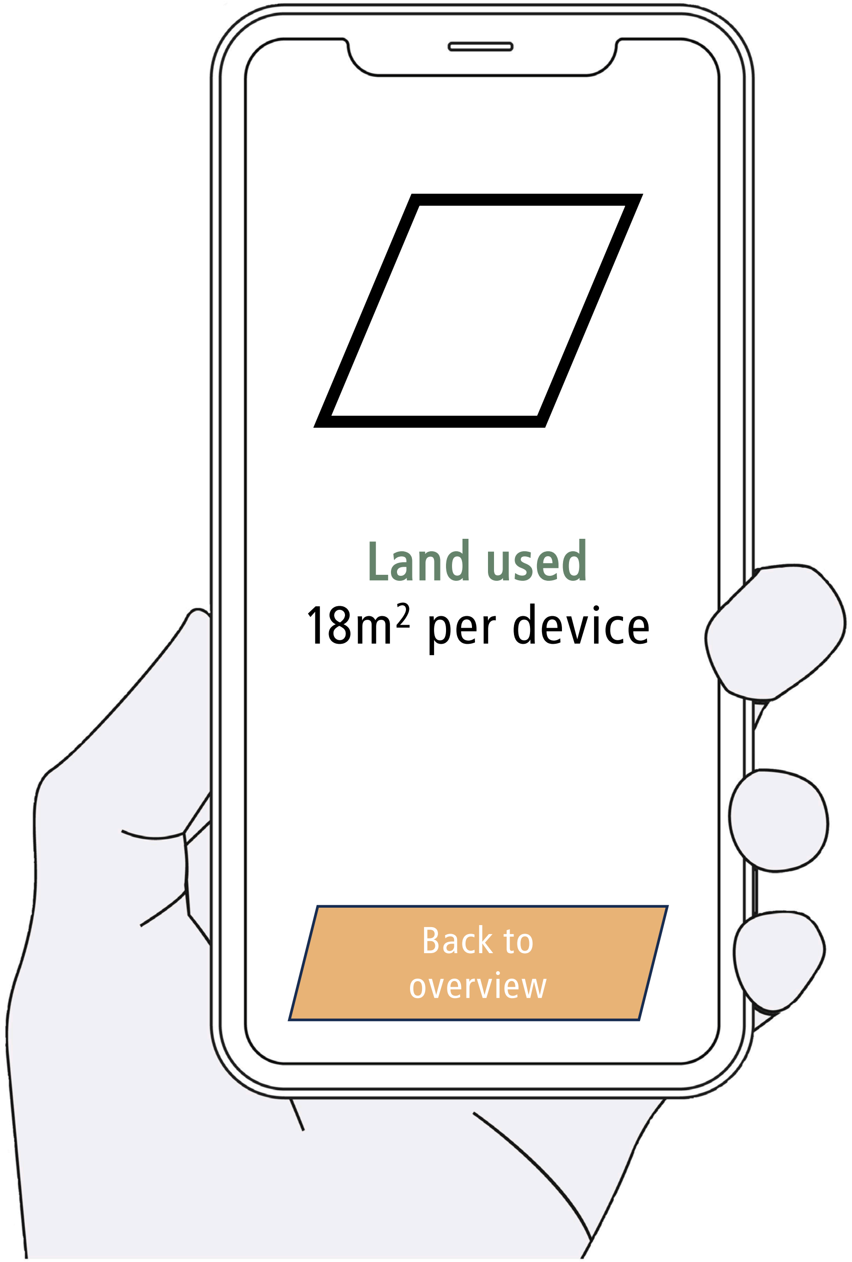
What does this mean?

18 m^2 doesn't seem like much until you realize it is about the size of a room in your apartment – for every smartphone (and member of the family).

And for 1.3 billion devices produced each year, the land used comes to about the size of Slovenia or Belize.

55% of the land footprint comes from packaging.
39% more from raw materials like glues and plastics used in manufacturing.
Just 5% from mining.

Land footprint does not necessarily imply that pristine wilderness or prime agricultural land is destroyed. But it's not pretty, either.



What can be done?

Obviously reducing the packaging would be the first measure. And like for water usage the EU is incorporating land use into its taxonomy framework and guidelines for production.

Producers must seek to exert influence through their supply chains.

Consumers could use information on land use provided to influence their purchasing decision or incentivize more long-term use.

Source
Friends of the Earth report, May 2015:
https://www.twosides.info/wp-content/uploads/2018/05/mind-your-step-report-76803.pdf

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What does this mean?

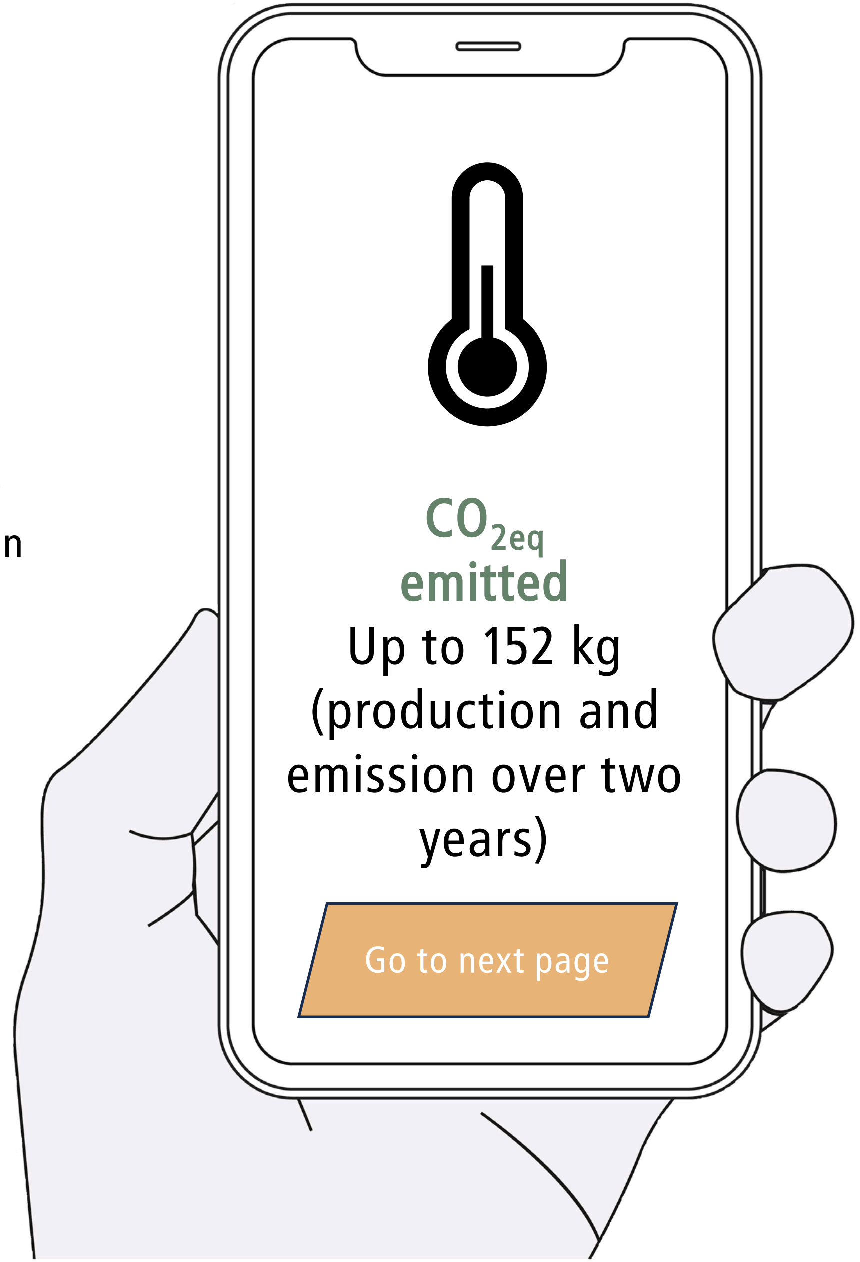
This is the classical carbon footprint of using a smartphone. To calculate it you do a so-called life cycle analysis. There are several tools for calculation available.

You have to add production, charging and network usage, plus possibly repairs.

Data traffic is a major factor. The total number for using a phone for two years can be between 87 and 152 kg of CO_{2eq} emitted. The numbers depend on specific devices and methods used.

The higher number (152 kg CO_{2eq}) corresponds to about the effect of a one-way flight Frankfurt-London (calculated by atmosfair.de).

For each of the billion phones.



What more is there to know?

The carbon footprint depends on the production (only once) and the time of the usage (ongoing). So it makes sense to look at the average number of kg per year.

The numbers on the left are calculated for a new device used for 2 years, then left in the drawer: usage comes to 44 to 76 kg CO_{2eq} per year. If the device is used for three years instead of two, the average drops to 38 to 68 kg CO_{2eq} per year.

If you use the phone for two years, replace battery and screen and then use it for two more years before recycling, the average is about the same as if you used it for three years

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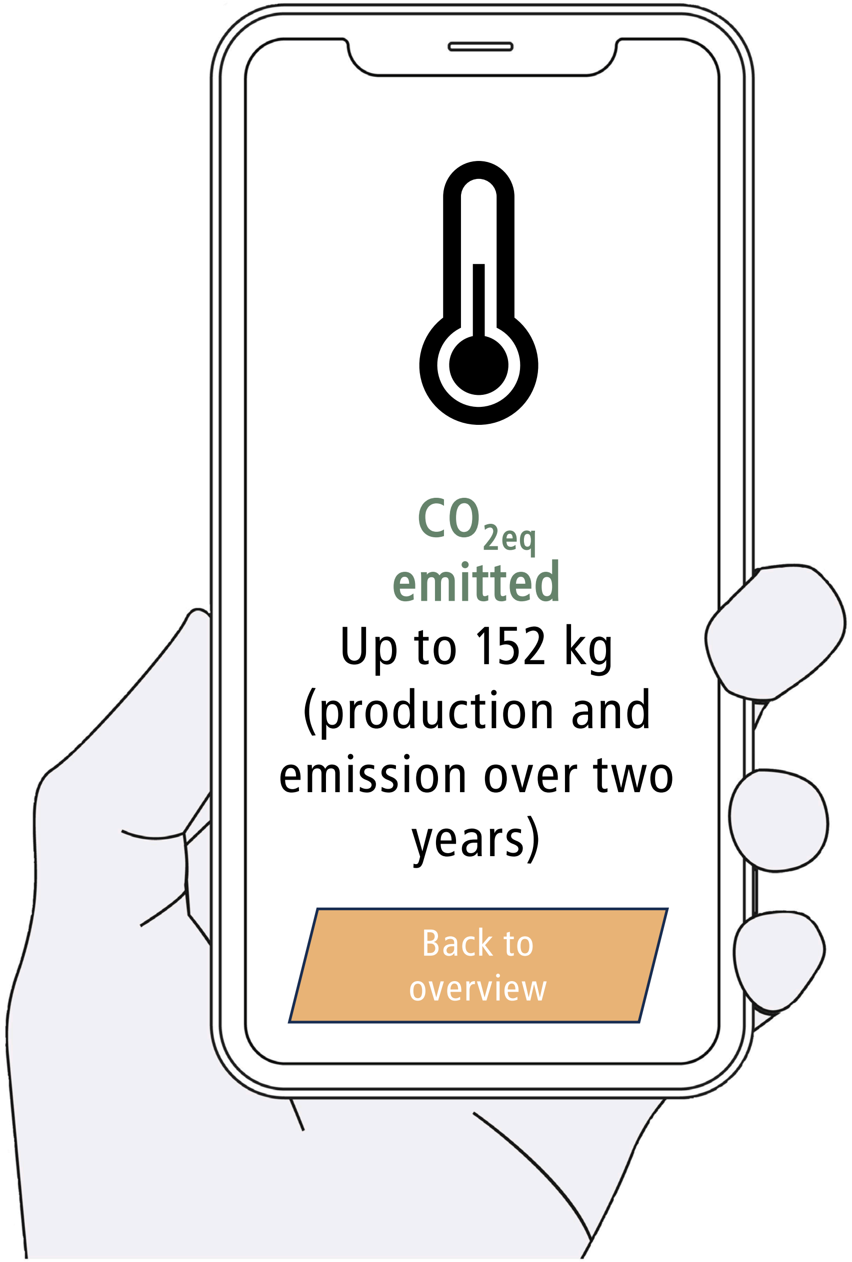
What can be done?

Using the device longer helps bring down the carbon footprint. But not dramatically.

A bigger difference could be achieved if

- the replacement parts had less of a footprint and were more standardized.

- the footprint of using mobile data were reduced at the datacenters and hubs, masts and antennas along the way.



Source
Life cycle analysis 1: Cordella et al, 2021
https://doi.org/10.1111/jiec.13119
Life cycle analysis 2, Ercan et al, 2016
https://www.researchgate.net/publication/308986891

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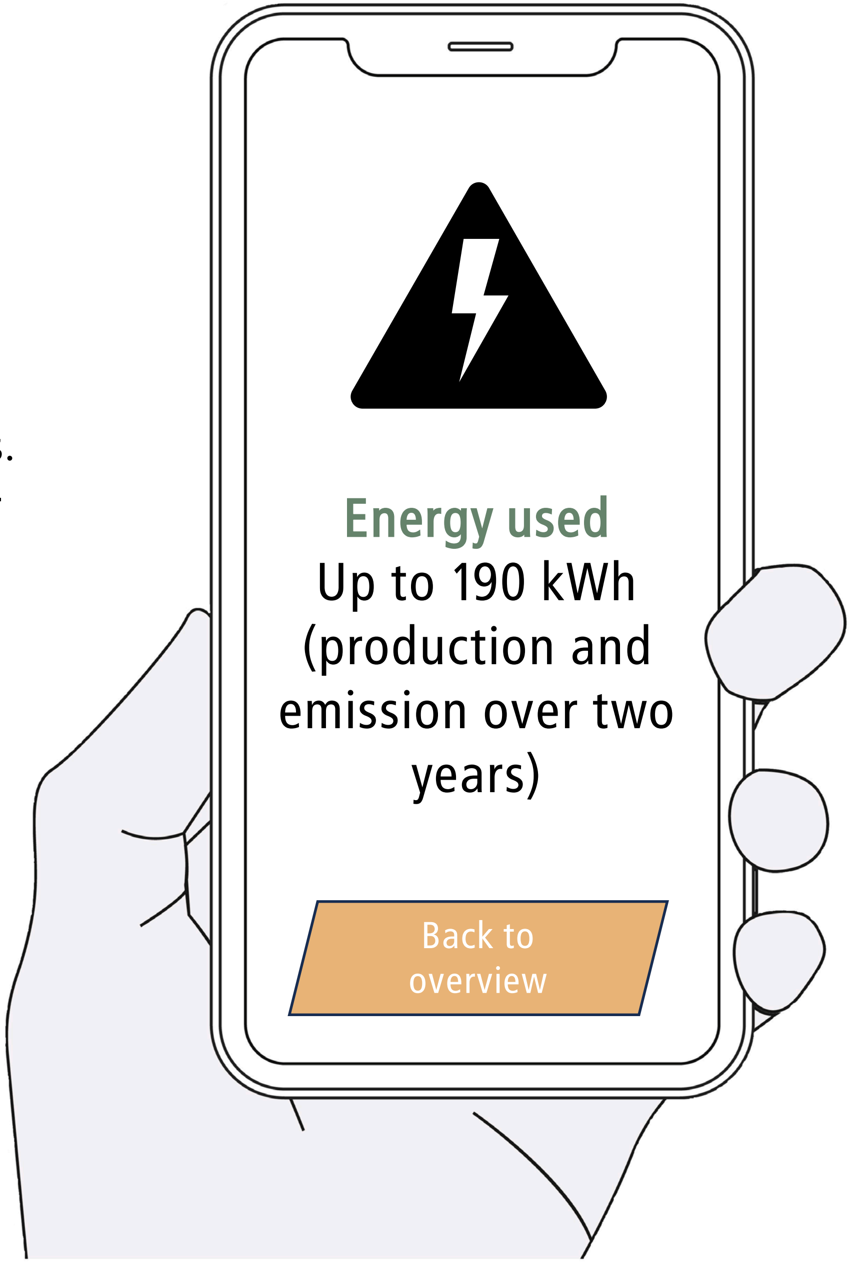
What does this mean?

You need a lot of energy to produce a smartphone, mostly electricity. Common estimates are around 60 to 70 kWh of so-called **embodied energy**.

And then you use electricity to charge the device and call up content from the net. That can be 40 to 60 kWh per year for average users. Combined this makes 140 to 190kWh for a two-year use phase.

To put that in relation: In a family of four living in Germany, the electricity use per person for the same two years is about 2000 kWh. So the smartphone takes up **7 to 10% of a person's total energy consumption**.



What can be done?

Some of the same arguments apply as for the carbon footprint because both topics are related:

- Consumers using the device longer.
- Producers making production less energy-intensive and components exchangeable.
- Network carriers making data centers run on green energy.

Sources
Smil, 2016, https://vaclavsmil.com/wp-content/uploads/17.MOBILESCARS.pdf
Ordoñez Duran et al, 2020
https://www.springerprofessional.de/en/analysis-of-embodied-energy-and-product-lifespan-the-potential-e/17916722
Ercan et al, 2016
https://www.researchgate.net/publication/308986891

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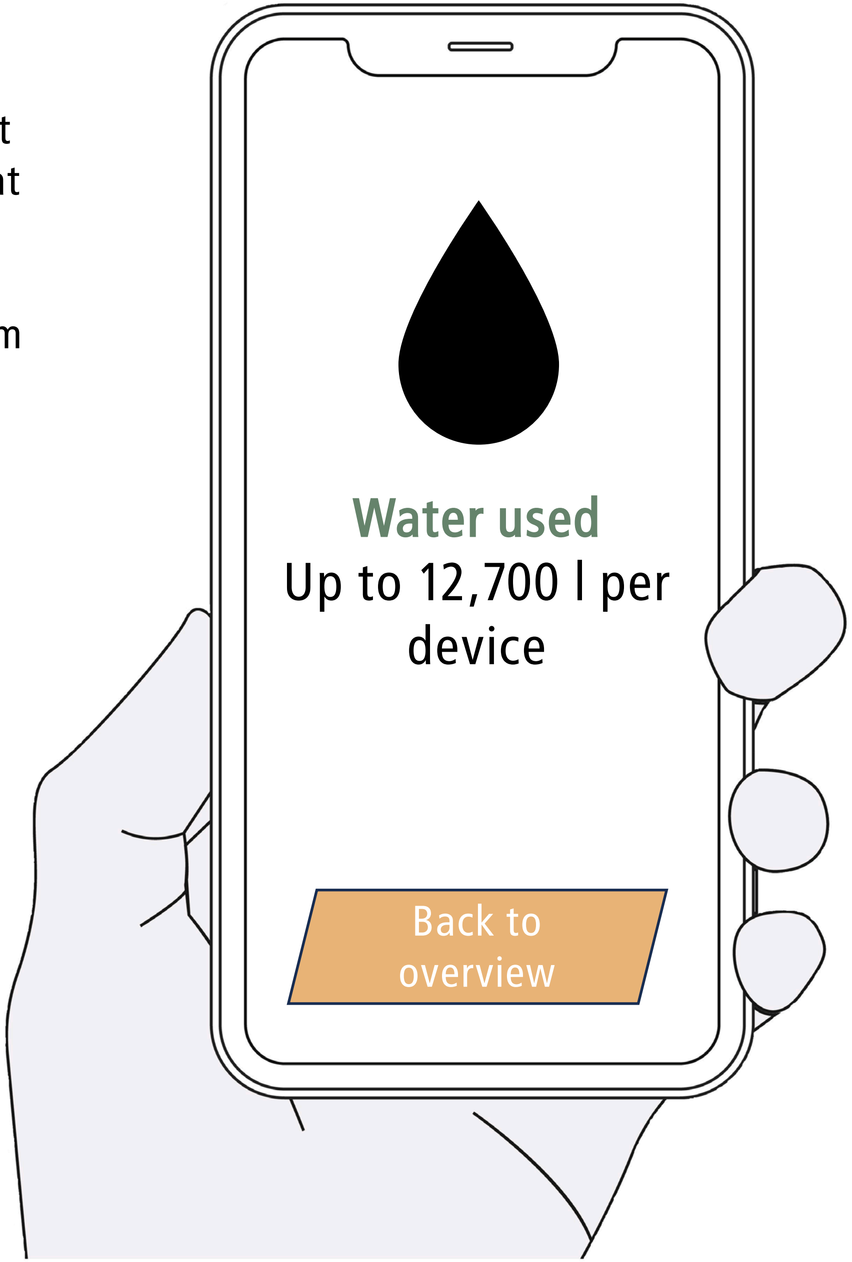
What does this mean?

Here we are calculating the water footprint with a method a „Friends of the Earth" report used in 2015. There are three components that are summed up:

- Blue water refers to fresh water taken from groundwater, lakes and rivers;
- Green water is collected rain;
- Grey water accounts for the amount of water degraded while diluting created pollutants to safe levels.

In the smartphone those three components make up 29%, 11% and 60%, respectively. Most of the latter is consumed because of chemicals in glues and lubricants used in manufacturing.



What can be done?

Improvement of manufacturing can have the greatest impact on this factor. In order to improve supply chains, producers are increasingly – either voluntarily or pressured by law – extending environmental reporting.

Consumers could use information on water use provided to influence their purchasing decision or incentivize more long-term use.

Source
Friends of the Earth report, May 2015:
Available here:
https://www.twosides.info/wp-content/uploads/2018/05/mind-your-step-report-76803.pdf

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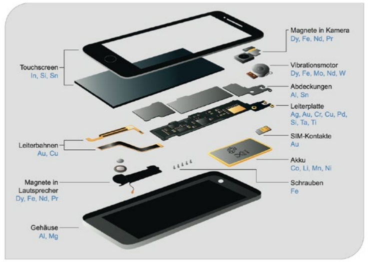
There are over 50 **metals** in the average smartphone. Plus non-metal components in screen glass or plastic casing.

Some of those are abundant like iron or aluminium. Others are rare or only found in a few sources that are controlled tightly by the countries where they are located.

In some cases the conditions of **mining** are very bad. They can be destructive for the environment and abusive for the people working in the mines and living close by.

Among the metals there are some that are very expensive, like gold or palladium.
Still the **combined worth of the metals in a smartphone is only about one Euro**.



Zerlegtes Smartphone und darin vorkommende Metalle (© BGR/PrinzMayer)

Click on graphs to see bigger versions

Back to overview

Click here to see a breakdown of the metal values.

Sources
Upper Graph: German resources agency DERA, Bookhagen and Bastian, 2020
https://www.deutsche-rohstoffagentur.de/……
Lower graph: Visual capitalist, 2021
https://elements.visualcapitalist.com/critical-metals-in-a-smartphone/

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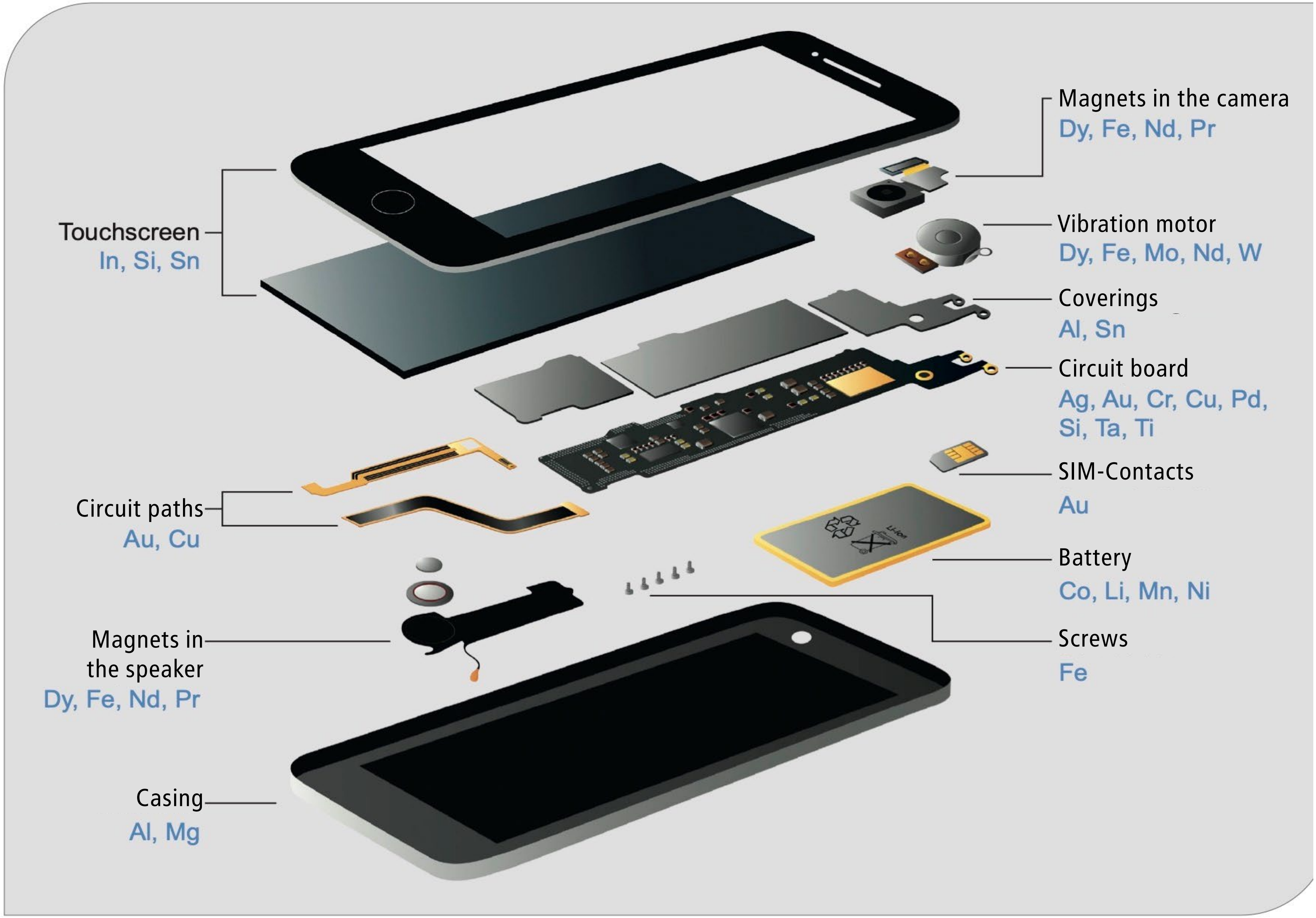

Explosion view of smartphone and contained metals (© BGR/PrinzMayer, [Source Link]())

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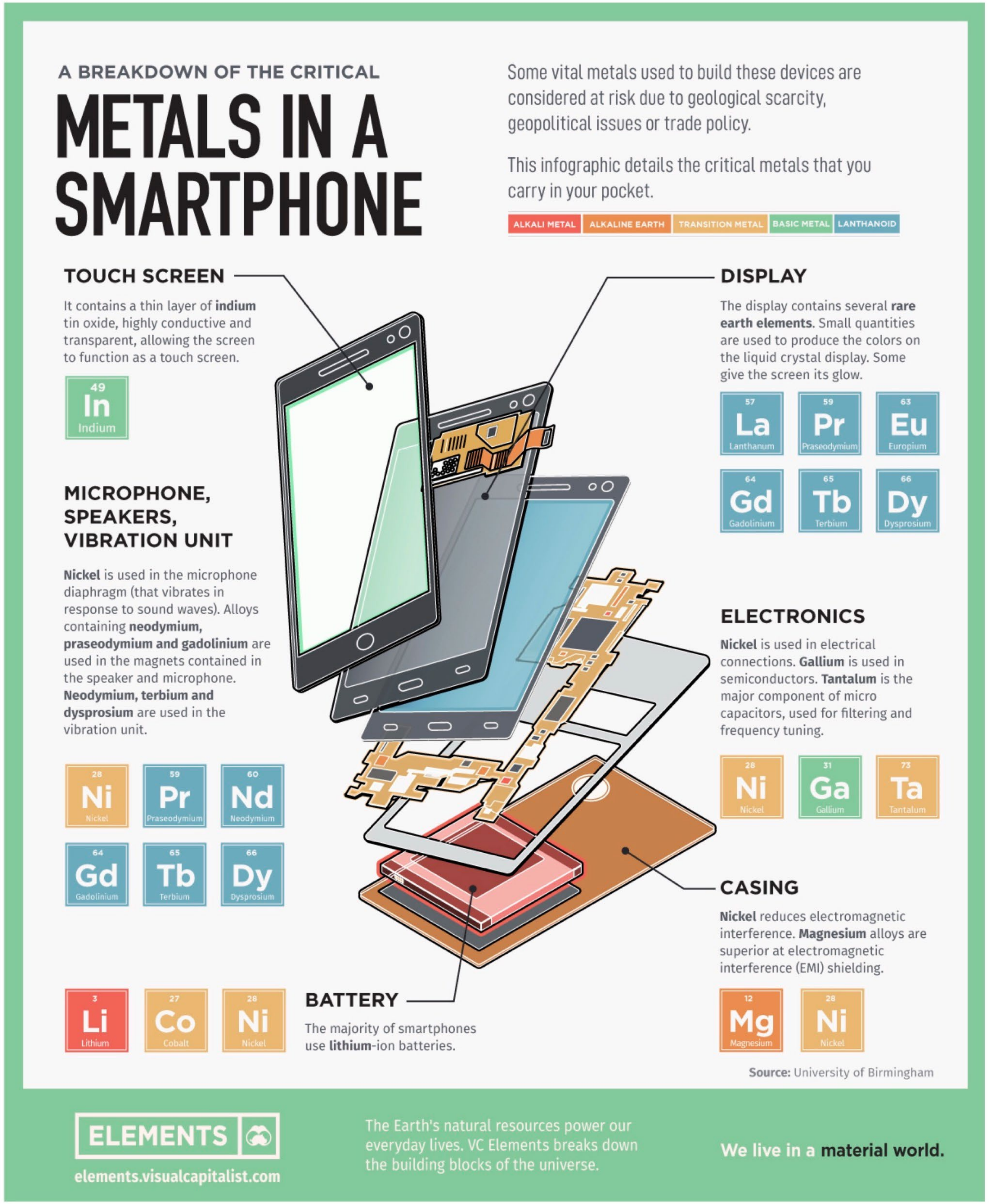
Source Link



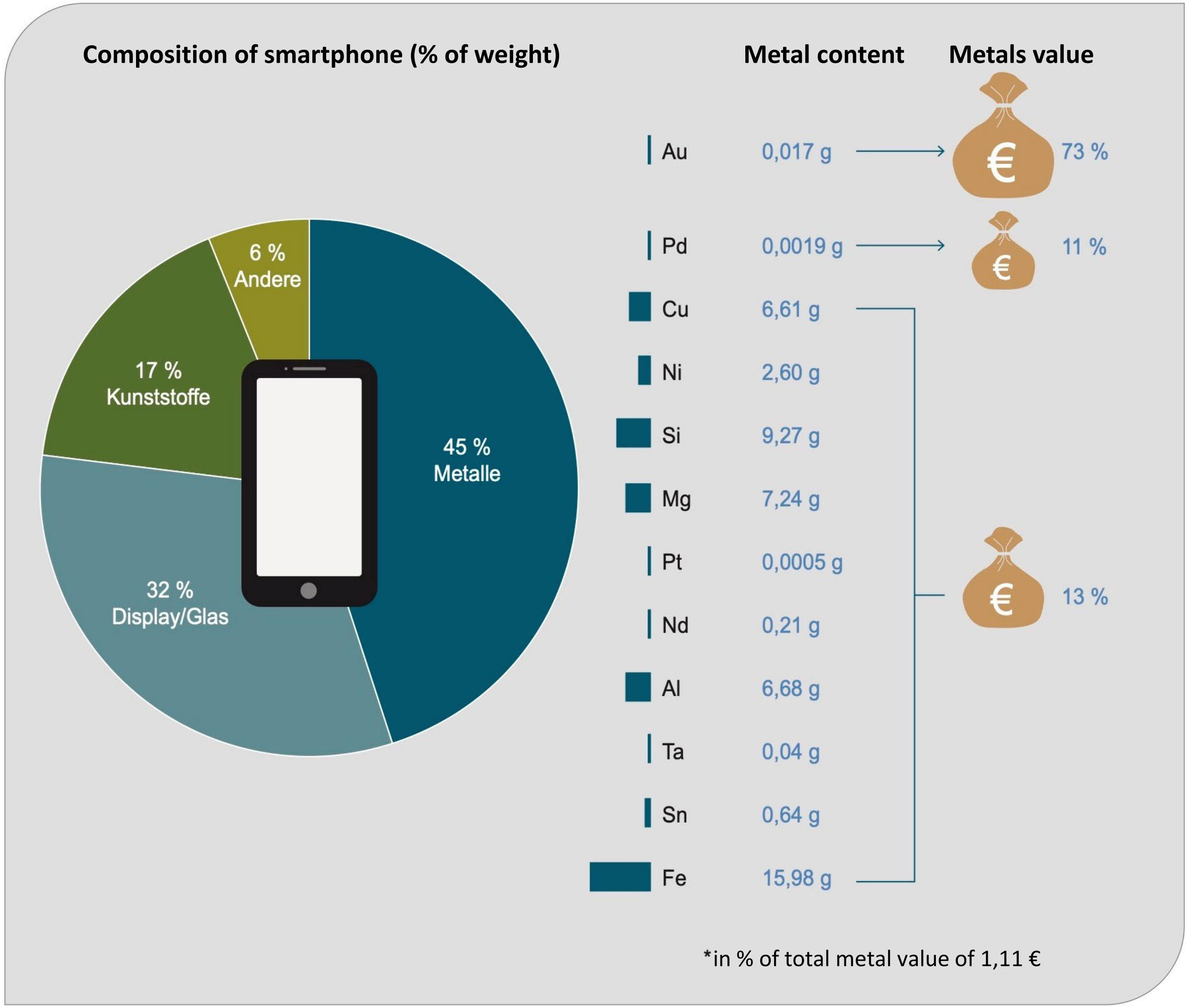


Fig 2: Average composition of smartphones (left); contents of 12 metals (middle, ordered by descending values). These 12 of the 53 metals make up 97% of metal value of € 1,11 in total (prices averaged over first half of 2020). Adapted from Bookhagen et al 2020 (© BGR/PrinzMayer, Source Link)

Click to go back

There are dozens of different metals in the average smartphone that are mined all over the world.

There are some countries in Africa like the DR Congo that supply much needed metals. Chile, Canada and Australia are also among the suppliers.

Many metals are mined in China where many smartphones are also assembled. Those resources might still travel far abroad to other sites to be put into components and then come back „home“ for final assembly.

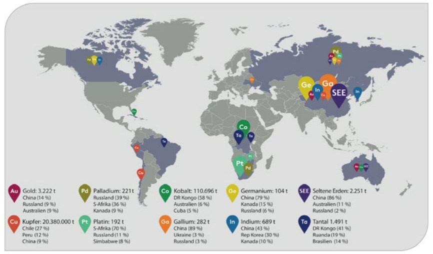


Abb. 5: Top 3 Abbauländer (Bergbauproduktionsdaten 2016) ausgewählter Metallrohstoffe, in Klammern prozentualer Anteil an Gesamtproduktion (© BGR/PrinzMayer).

Origins

Click on graph to see bigger version

Back to overview

Click for a world map illustrating global control over metals used in smartphones.

Sources

German resources agency DERA, Bookhagen and Bastian, 2020 https://www.deutsche-rohstoffagentur.de/……

USGS-Map: https://pubs.usgs.gov/publication/gip167

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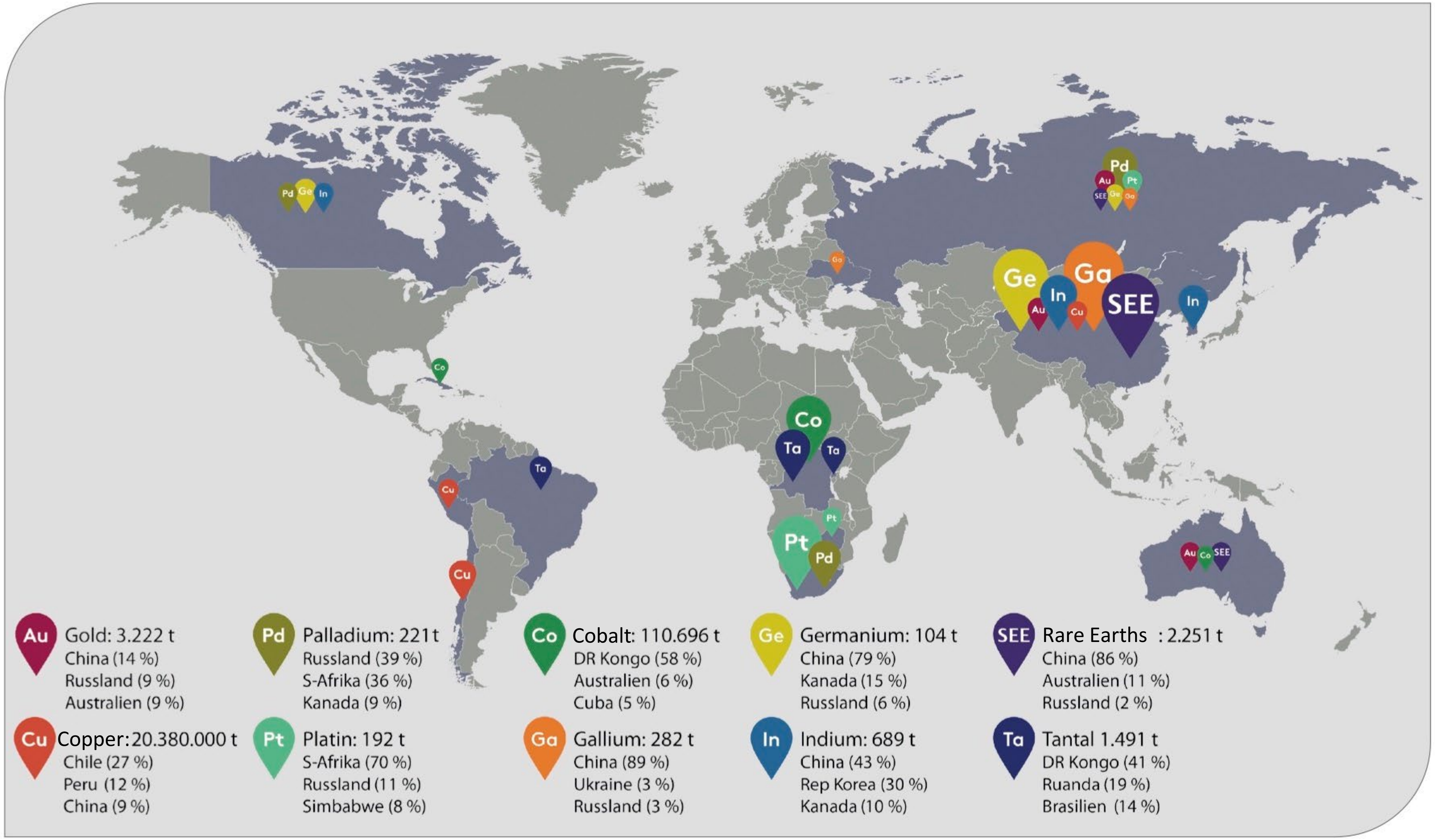
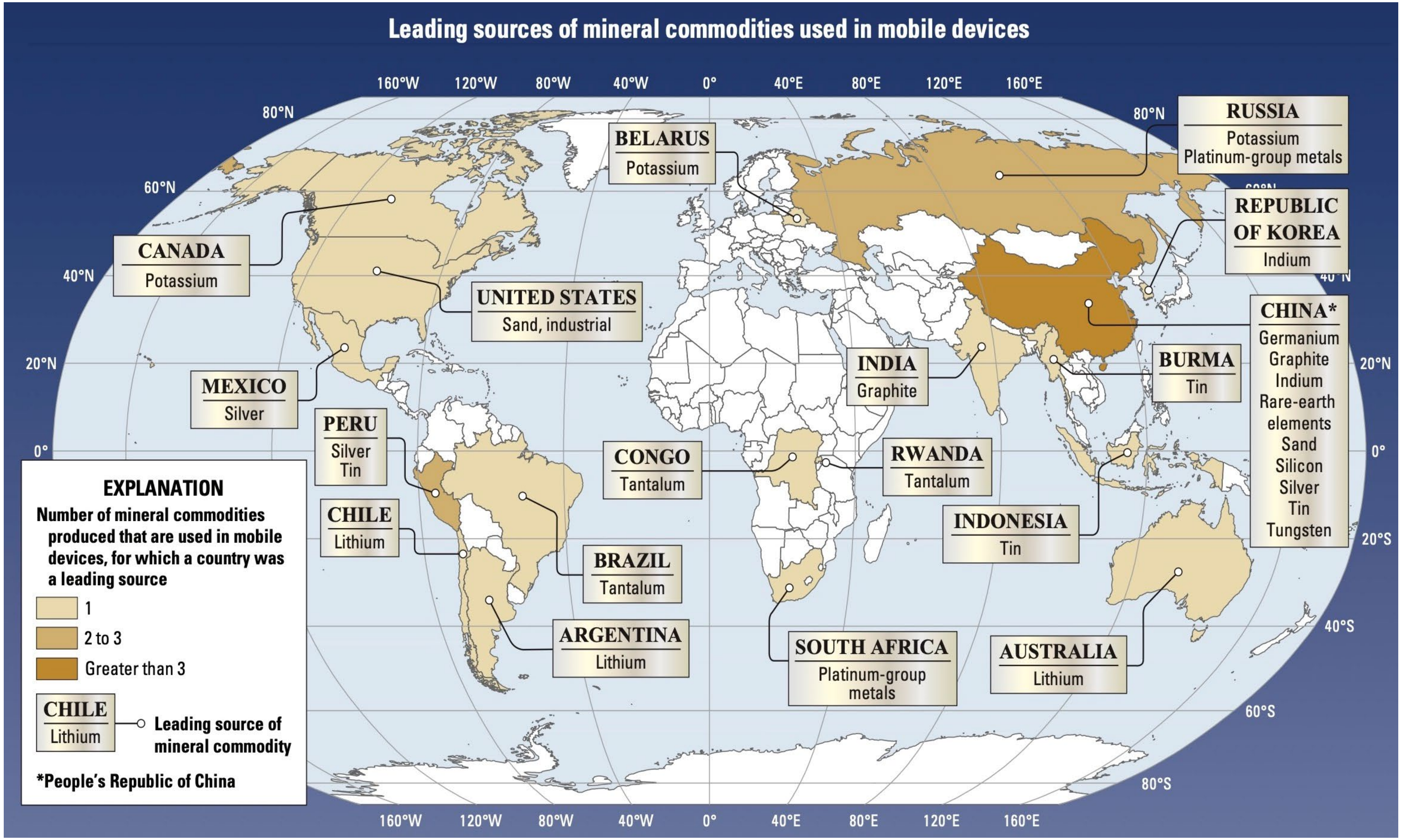


Fig 5: Top 3 source countries (mining data 2016) of selected metal commodities (in brackets the percentage of total production) © BGR/PrinzMayer (captions translated where needed, [Source Link](#))



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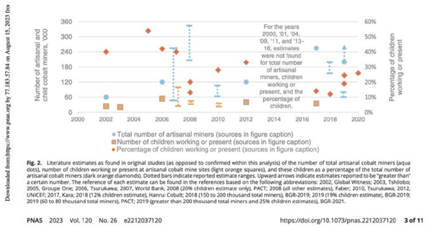
[Source Link]

Child labor in so-called „artisanal mines“ in countries like DR Congo has caused much suffering but also drawn much international attention.

This graph shows a study that is based on published estimates because there are no official statistics, naturally. Estimates range from 60,000 to 100,000 children for the period between 2002 and 2020 with a peak around 2006.



Child labor in cobalt mines

Click on graph to see bigger version

Back to overview

DR Congo became a primary supplier of cobalt when demand went up fast after the year 2000. The artisanal mines produced about 10% to 15% of the metal both in 2002 as well as in 2020 –while total supply went up by a factor of ten.

But that is not the whole picture: Artisanal mining in DR Congo produced more than 25% of global supply from 2001 to 2012. In 2005, more than half of the world’s cobalt came from the artisanal mines – while working and production conditions in them remain unregulated and dangerous.

Source
Gulley, 2023, PNAS, https://doi.org/10.1073/pnas.2212037120

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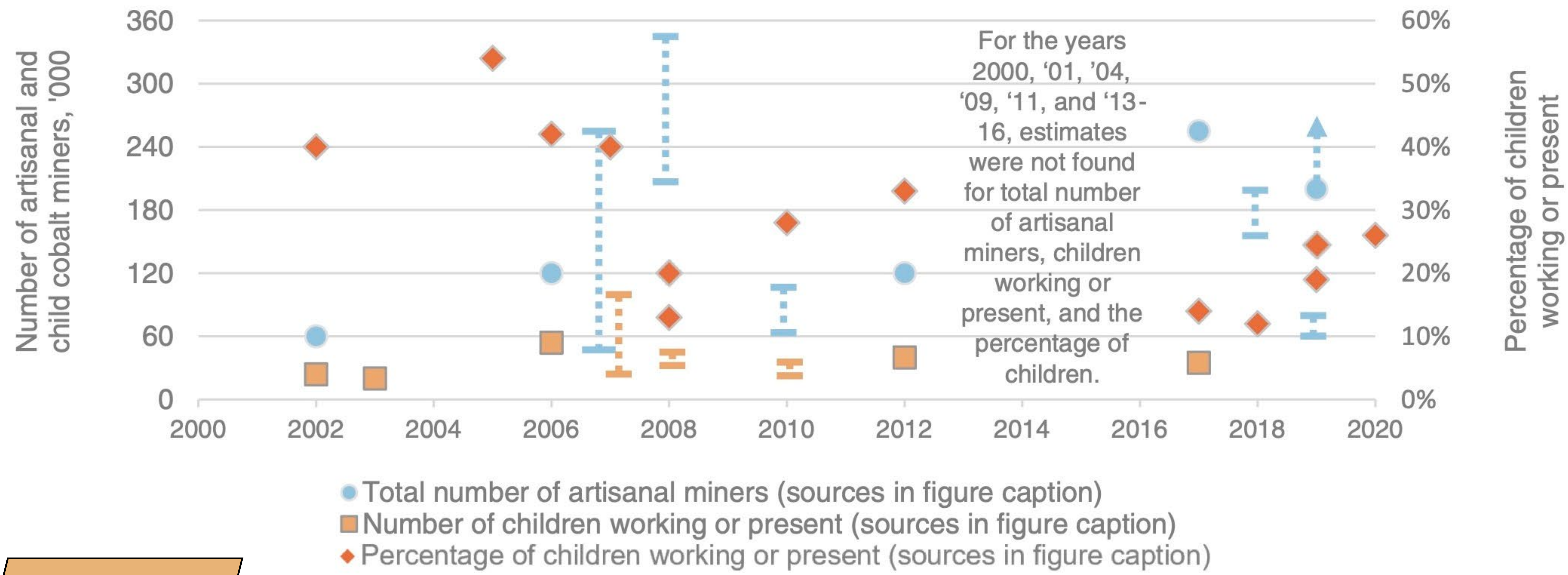
Child workers in cobalt mines in DR Congo between 2002 and 2020

(number and percentage of minors)

The following pages will guide you through the details of this graph.



Source: Gulley, 2023, PNAS, https://doi.org/10.1073/pnas.2212037120

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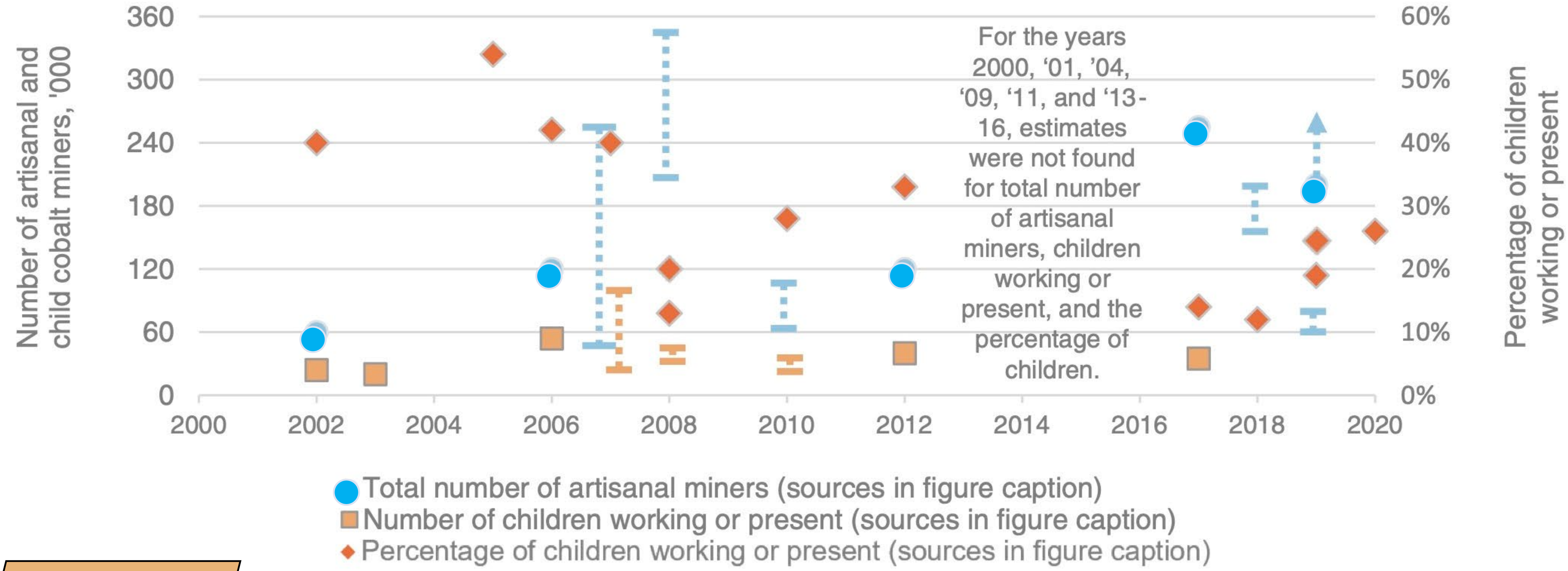
The blue dots show estimates of how many people in total worked in those mines.
It started at 60,000 in 2002 and quadrupled until 2019.
Dotted blue brackets show less precise estimates.



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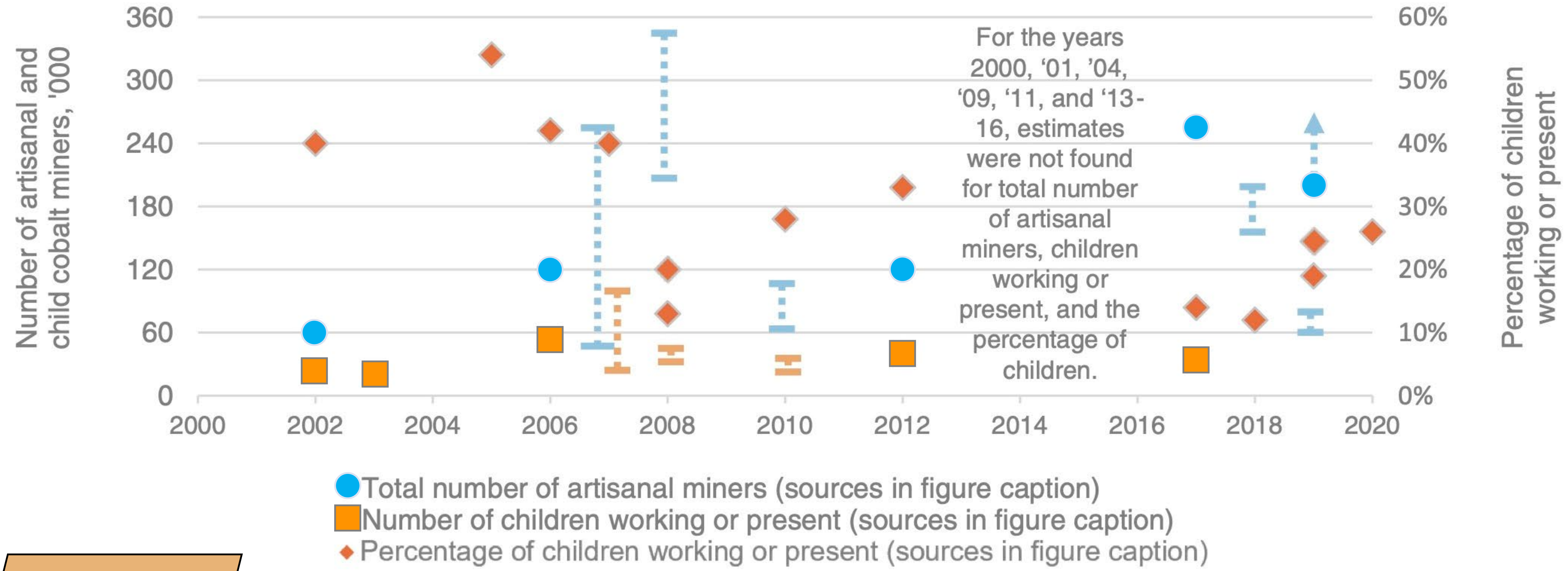
Source: Gulley, 2023, PNAS, https://doi.org/10.1073/pnas.2212037120

Orange squares show how many **children** worked in the mines.
Dotted pink brackets show less precise estimates.
Numbers peaked at almost 60,000 in 2006 and slightly decreased afterwards.



Source: Gulley, 2023, PNAS, https://doi.org/10.1073/pnas.2212037120

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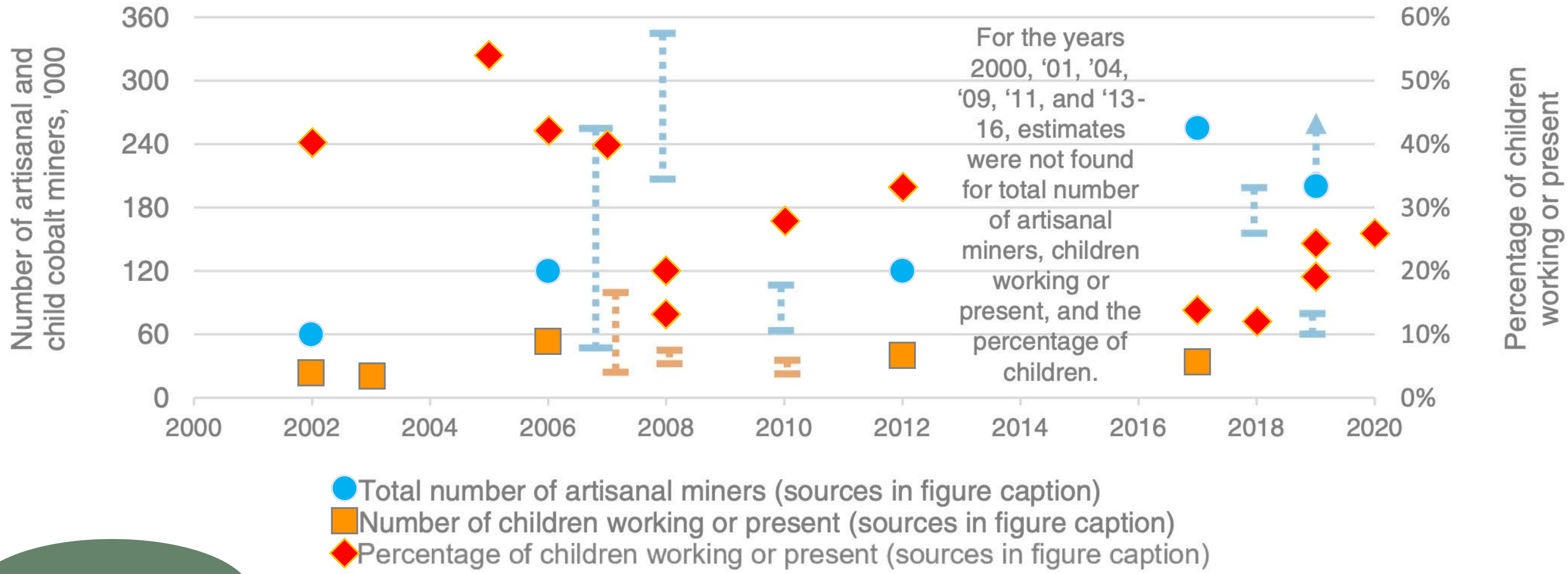
Red diamonds show the **percentage** of workers who are minors.
It started at 40% in 2002 and peaked at 55% in 2005.



Source: Gulley, 2023, PNAS, https://doi.org/10.1073/pnas.2212037120

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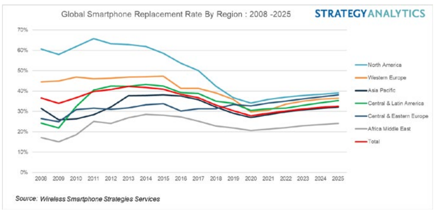
The numbers here show how many phones are **replaced within a year**. E. g. the numbers for North America (66% in 2011) mean that two thirds are replaced, meaning the average phone is used for 1.5 years.

There used to be huge differences between high income and low income countries. They are still visible today but they are shrinking.

In Africa and the Middle East, in 2025 the devices are expected to be used for around 4 years (25% replacement rate). In North America it will be about 2.5 years (40% replacement rate).



Replacement cycles

Click on graph to see bigger version

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Why do people want to replace their phones? And what can be done about it?

How often would people like to switch to a new phone?

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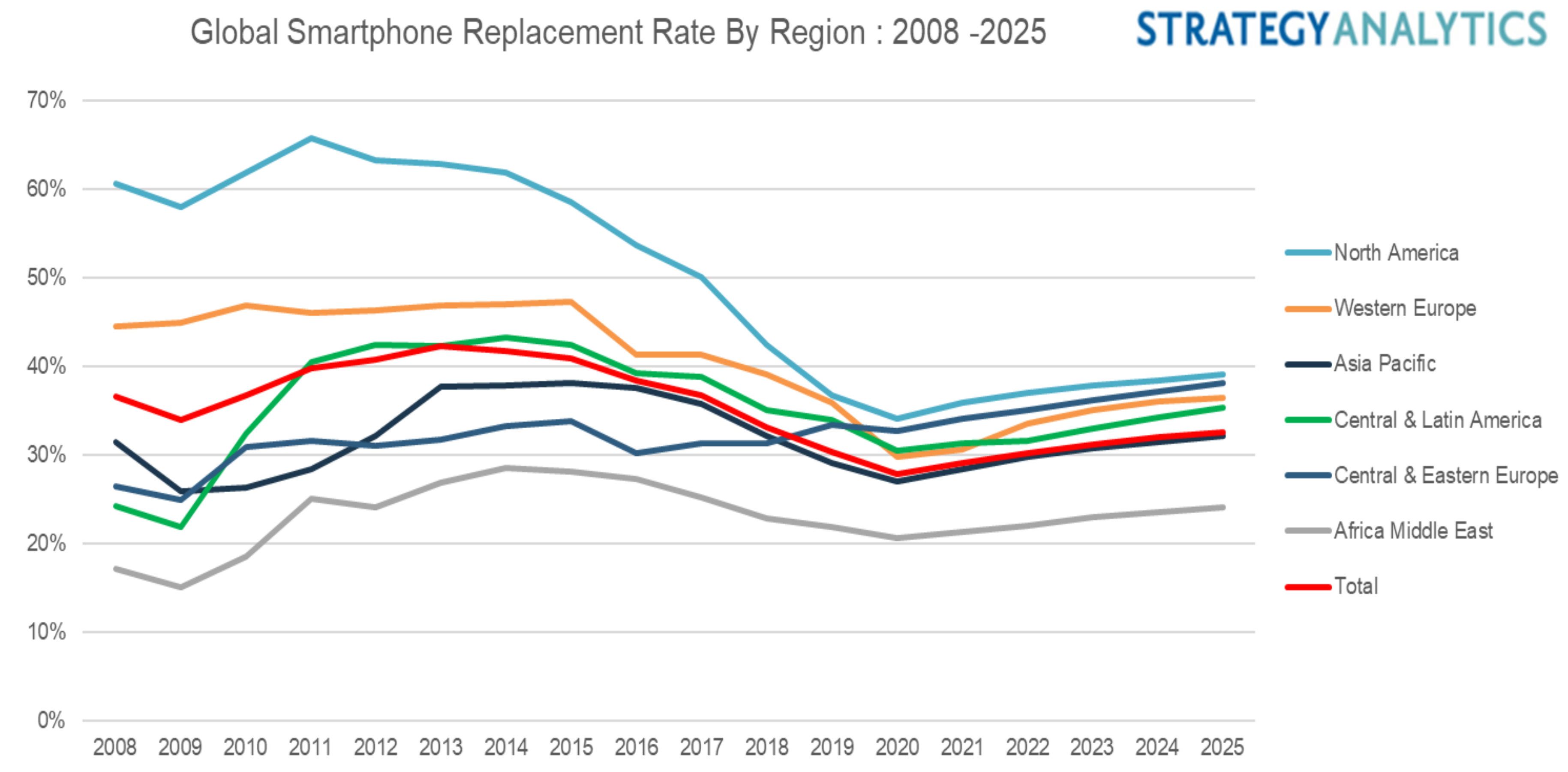
The numbers here show how many phones are replaced within a year. E. g. the numbers for North America (like 66% in 2011) mean that two thirds are replaced, so the average time they were used was 1.5 years.
In Africa and the Middle East, in 2025 the devices are expected to be used for around 4 years (25% replacement rate).



Source: Wireless Smartphone Strategies Services Source Link

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Arguments for replacing an intact device and possible changes to affect consumer decision making

(German Advisory Council on the Environment, translated)

Arguments for purchase	Examples of measures to change the context of the decision situation
Performance of battery, processor, storage decline	Present instructions on care and maintenance of device in a way to draw attention (to slow down loss of performance)
Software support discontinued	Set minimum time for software updates and emphasize that in the description of the model
Valuation of device declines (in terms of looks, usage traces, habituation)	Use durable materials for sensitive parts; provide wear and tear parts long-term, inexpensive and replaceable; offer new design options with replacement parts; add new features in software updates
New phone included in contract, newer models are required for certain features	Decouple provider contract from purchase of device; allow upgrades to new functionalities via software updates; modular smartphones would allow replacing only specific components to increase functionality (like cameras)
New device sparks excitement and curiosty, provides enter-tainment, boosts social status	Rent or lease systems; provide alternative feelings of reward („less environmental degradation, less waste“, „use a year longer and save x kg CO_2 “, „only 10 % manage to use the smartphone for 4 years“)

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Source Link

SRU 2023

Preferred usage period for smartphones – by sociodemographic criteria
(German Advisory Council on the Environment, translated)

	Total	Region		Gender		Age			
		West	East	male	female	18–29 years	30–44 years	45–59 years	45–59 years
every year or more often	13 %	14 %	6 %	14 %	12 %	30 %	12 %	10 %	3 %
I would prefer to use my current device as long as possible	42 %	41 %	48 %	40 %	44 %	25 %	37 %	46 %	59 %

Question: Now it's about your preferences regarding the usage duration of your devices. Assuming you had unlimited money and time, in what interval, every how many years, would you prefer to buy a new smartphone?
N = 790 repondents from age 18 years old with a smartphone in use. This shows two of the seven options to answer.
Nutzungsdauer (s. HIPP et al. 2021, S. 19)

Quelle: HIPP et al. 2021, S. 20

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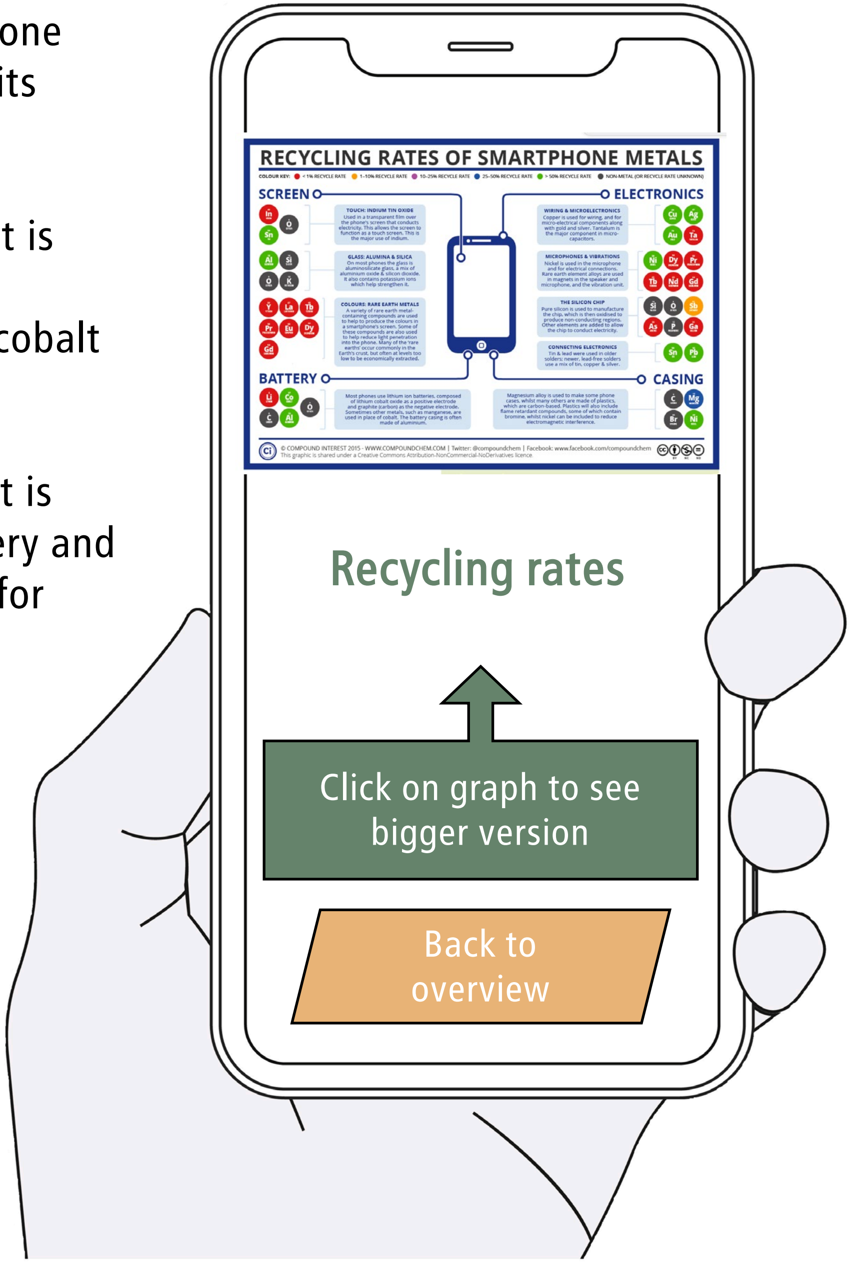
Source Link

Very little of the metal contents of the smartphone actually get reused after the device has ended its useful life.

Green in the graph means more than 50 percent is recycled: That only happens for gold and silver, copper and tin, aluminum, and lead as well as cobalt and nickel.

Red in the graph means that less than 1 percent is recyled. This starts with the lithium in the battery and the tantalum in the electronics but is also true for rare earth metals and others.



What can be done?

Generally, a redesign of the device would help a lot. If cases are easier to open and components easier to take out, those could be reused or recycled in a more dedicated fashion.

Also consumers should (be incentivized to) return devices no longer in use to specialized recycling centers.

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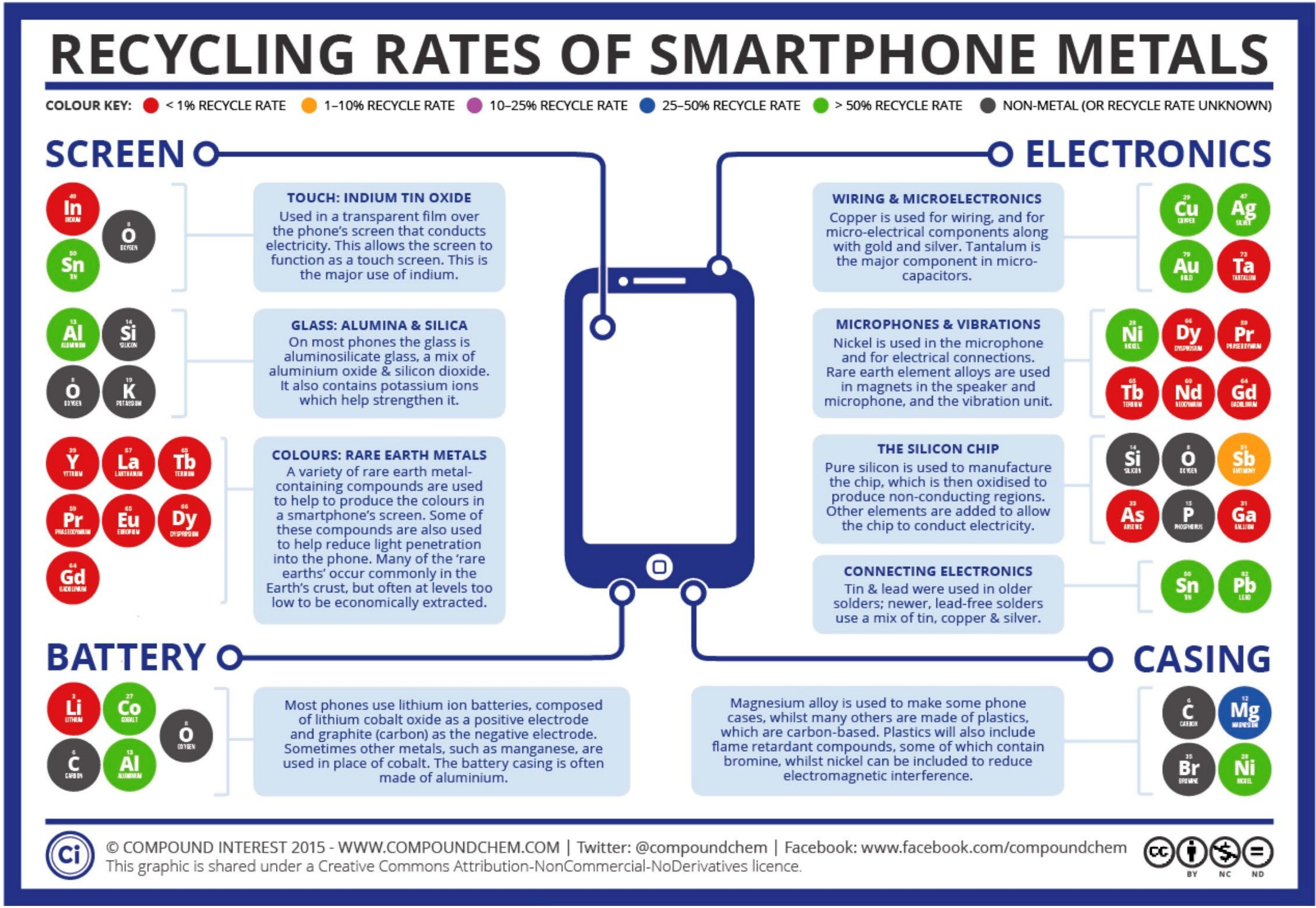

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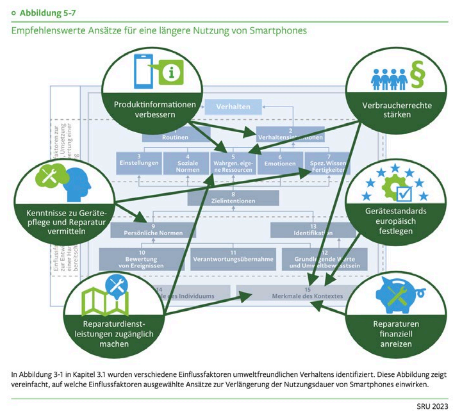
This figure is from a 2023 report of the German Advisory Council on the Environment (SRU). They thought of at least **six ways to influence consumers to use their smartphones longer**.

Central ideas are to spread product information and especially knowledge on ways to repair devices, make repair services accessible and provide financial incentives for using them.

That is flanked by standards for devices fixed by the European Union and by strenghtening the rights of consumers to actually get repairs.

Why do people want to replace their phones? (repeated from a previous section)



Behavioral change & choice architecture

Click on graph to see bigger version

Back to overview

The council says that politics should target consumer behavior after measures for producers are in place.

The members first constructed a model of how behavior is guided according to the psychological literature. There are quite a few steps. That is in the background of the figure.

Then the six proposals are each attached to one or two of those stages: context of decisions made, personals norms, knowledge and others.

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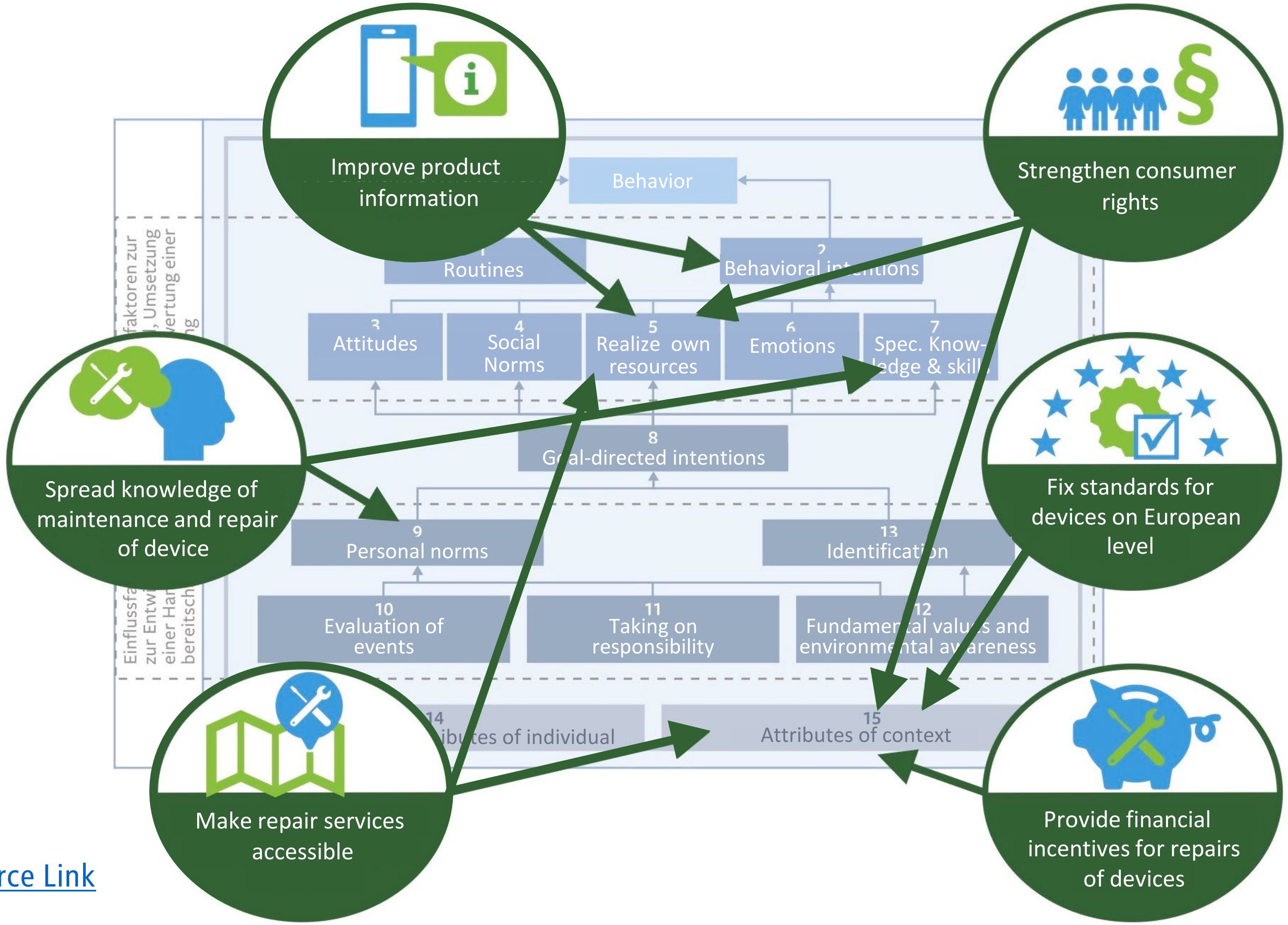
Advisable approaches for a longer usage phase of smartphones
(German Advisory Council on the Environment, translated)

For more information
on the approaches,
please refer
to the original source
(in German).



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This presentation was created by **Christopher Schrader** as part of the Alexander von Humboldt Foundation's **Humboldt Residency Programme 2023** on the topic of „Our Precious Resources".

Find out more about the programme and the cohort's work on Resource Extraction and Choice Architects here.

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