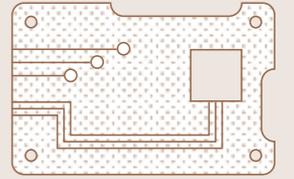


# Precious metals from the circular economy

It is high time we made use of bio-based technologies in order to utilise secondary resources, and not just increasingly scarce primary resources, for creating sustainable added value. Microorganisms can help us in this respect.

— There is a growing demand for metals, especially precious metals such as gold, silver, platinum and palladium, resources that play a key role in many high-tech applications. But precious metals are rare and increasingly difficult to come by. The modern circular economy aims to make them available from waste streams as well.

— BRAIN is a pioneer in the bioeconomy sector, and has developed solutions for this purpose based on modern biotechnology processes. In the green mining sector, the company offers enrichment and extraction processes for a more environmentally friendly treatment of metal ores from mining operations. For urban mining, BRAIN has developed bio-based processes for extracting precious metals from secondary and waste streams.



## 40 m

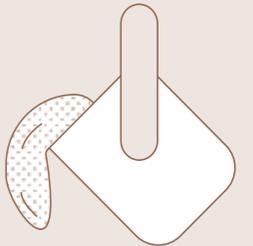
Every year, we produce over **40 million tonnes of electronic waste**. One tonne of computer boards alone may contain up to 250 grams of gold and one kilogram of silver.

## 3 t



Bottom ashes from waste incineration are added to asphalt for building roads. That means **up to three tonnes of gold** and incredibly large quantities of other metals **are incorporated into German road surfaces every year**.

## 20 kg



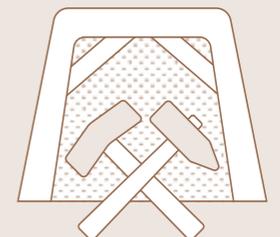
Each year, the steel and metallurgical industry produces hundreds of tonnes of dust, sludge and ash that contain precious metals. **Metal slags**, for instance, can contain up to 20 kg of gold per tonne, as well as many other metals.



## 40

It takes about **one gram of gold to manufacture 40 mobile phones**, which have an average service life of only two and a half years. To extract this quantity of gold, about a tonne of ore has to be mined and processed.

## 4 km



Eight of the **ten deepest mines** are located in South Africa and reach depths of up to four kilometres. The ore content of newly mined deposits is steadily declining.



The first BRAIN BioXtractor pilot plant is located at BRAIN's head office.

## The BRAIN BioXtractor ...

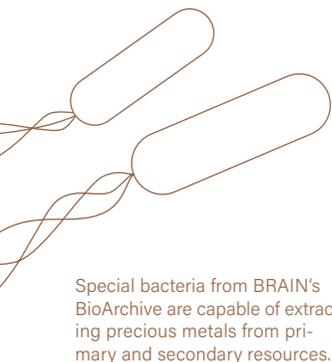
... is a **pioneering technology** used in the bioeconomy for next-generation metal extraction. It is based on biotechnological processes and microorganisms identified in BRAIN's BioArchive.

... offers **innovative, efficient and safe biological process solutions** for extracting metals from various secondary and waste streams as well as primary resources.

... can **extract further substances from residual material streams** in order to use biologically purified, valuable material in the construction industry, for example.

... is a **mobile, fully equipped, closed-circuit plant on a pilot scale** that is suitable for on-site process demonstrations and can be adapted to specific requirements.

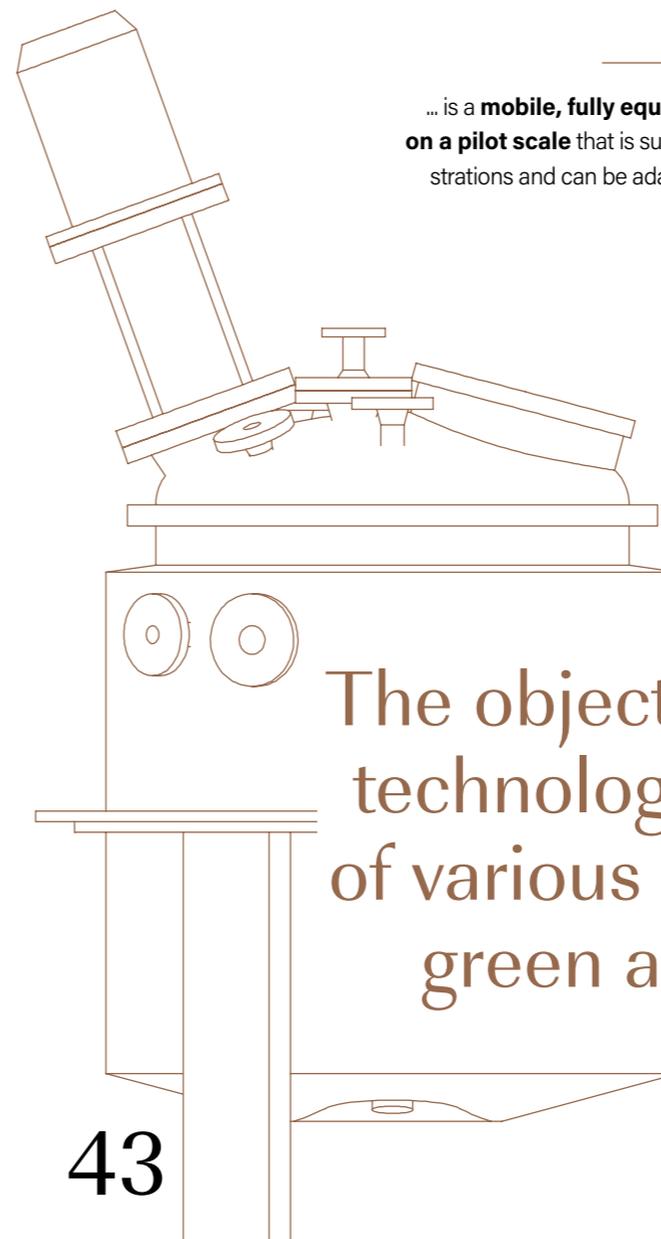
... is a **sustainable answer** to declining ore yields, better environmental protection and volatile markets, as well as a promising option for covering future demand for precious metals.



Special bacteria from BRAIN's BioArchive are capable of extracting precious metals from primary and secondary resources.

— The natural protagonists in these processes are microorganisms that were identified in BRAIN's BioArchive and further developed in the laboratory. These bacteria, for which BRAIN holds property rights, process primary and secondary resources and extract precious metals with a significant yield that sometimes exceeds 90 per cent, depending on the starting material and metal concerned.

— This technology has been successfully transferred from laboratory to pilot plant scale in the 2016/17 business year. In August 2017, the first BRAIN BioXtractor was set up at the company's head office in Zwingenberg. This demonstration plant will make it possible to process up to six metric tons of raw material per year.



The objective is to partner the technology for the treatment of various resource streams in green and urban mining.

# The innovation lies in the high yield our processes offer

An interview with Dr Guido Meurer, Member of BRAIN's Management Board and Unit Head Producer Strain Development, and Dr Esther Gabor, Programme Manager Green & Urban Mining.



**You have developed microorganisms and the corresponding processes for recovering metals from waste streams and electronic waste. What makes these streams so interesting?**

**GUIDO MEURER**

Processing secondary and waste streams offers advantages in terms of a sustainable circular economy. In the final analysis, this also offers huge business potential because precious and high-tech metals are extremely coveted and costly, and mining yield rates are declining. That is especially significant for resource-poor countries like Germany. For these streams, our bio-based processes enable a yield of up to 95% for gold, and almost 100% for other metals. That puts us in a good position as compared with traditional chemical processes.

**How did you identify the right bacteria for these processes?**

**ESTHER GABOR**

BRAIN has a large BioArchive with comprehensively characterised microorganisms. We can use our sophisticated screening processes to search through this archive based on specific requirements. But this archive, which we term "nature's toolbox", represents only a fraction of natural biodiversity. Sometimes we specifically set out to identify new product candidates. We don't have to travel far to find them, either. But we do look out for local habitats where we presume these candidates may live.

If you are looking for microorganisms that are supposed to extract silver at a later stage, you choose locations where silver can probably be found in the soil, and collect soil material there. In recent years, we have therefore made trips to closed-down mines and collected innumerable microorganisms that we subsequently analysed, selected and optimised.

**What makes biological "gold digging" so attractive, apart from the price of gold?**

**GUIDO MEURER**

For centuries, gold has held high cultural importance, and is also an important currency reserve and investment. But gold, as a precious metal, is also used for many technical applications. Of all the raw materials obtained by mining, gold is one of the most versatile. So it would be a shame for it to land on the scrap heap, or to be more accurate: it shouldn't be allowed to remain there. We can well imagine that 'BioX gold' from our BioXtractor will be incorporated into high-tech applications in the foreseeable future.

**About five per cent of gold is currently being mined using biotechnological processes, is that correct? What's special about the BRAIN process?**

**GUIDO MEURER**

At present, biological processes are only a preparatory step in extracting gold from ore, where they make subsequent leaching with chemicals more effective. In our processes, which focus on biology, there is no need for the addition of chemicals.

**There are a number of processes for obtaining metals from primary or secondary resources. Which are you working on?**

**GUIDO MEURER**

BRAIN has developed a variety of biological processes that can be used for specific starting materials and scaled up to different volumes. Here, we are speaking of bioadhesion, one technical variant of which is also termed bioflotation. Other processes are biosorption and bioleaching. Basically, all three processes are suitable for extracting precious metals, and they can be intelligently combined with each other.

**Have you applied for patents, and are research partnerships in place?**

**ESTHER GABOR**

Yes, we have applied for international patents both for the technological process and for the microorganisms used in this process. The first patent specification in this field of research was submitted in 2008. Since 2013, our research work has been embedded in the ZeroCarbFP innovation alliance supported by the German Federal Ministry of Education and Research (BMBF).

“We can well imagine that ‘BioX gold’ from our BioXtractor will be incorporated into high-tech applications in the foreseeable future.”

Dr Guido Meurer

**How much starting material can you utilise in the BioXtractor, and how much precious metal do you expect to obtain?**

ESTHER GABOR

We expect to be able to process several tonnes of starting material per year in our pilot plant. Of course, it depends on the material itself how much gold or silver we obtain from it. We reckon we will be able to extract precious metals up to kilogram scale each year with such a plant.

**Do your processes call for special safety precautions?**

ESTHER GABOR

We developed the bacteria for our applications by means of classical biological processes, and work with commercially available materials as well as natural biological materials and processes that pose no risk to human health or the environment. So no special safety precautions are required in general.

**Is it conceivable that your technology could be used in further fields of application?**

ESTHER GABOR

In principle, the processes can also be applied to highly valuable rare earth metals or basic metals such as copper. In fact, we have already done this successfully. But biological processes may also make sense for recovering heavy metals or other undesirable substances from ash, besides metal extraction as such. The purified residual mineral streams can then be used in the construction industry.

**How could the mining programme make contributions to BRAIN's turnover?**

GUIDO MEURER

By entering into partnerships, BRAIN benefits from payments that depend on its personal research contributions and milestone payments. We will also generate licencing fees when the findings and products are marketed. But those are all matters to be negotiated with our future partners.

**Have you already signed partnership agreements?**

GUIDO MEURER

One research partnership has already been in place for several years in the field of green mining. With regard to urban mining, i.e. the utilisation of secondary and waste streams, we are in touch with several companies from various sectors of industry that are interested in our technology and want to take a closer look at our BioXtractor. I can't give you any further details at the present time (end of business year 2016/17).



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