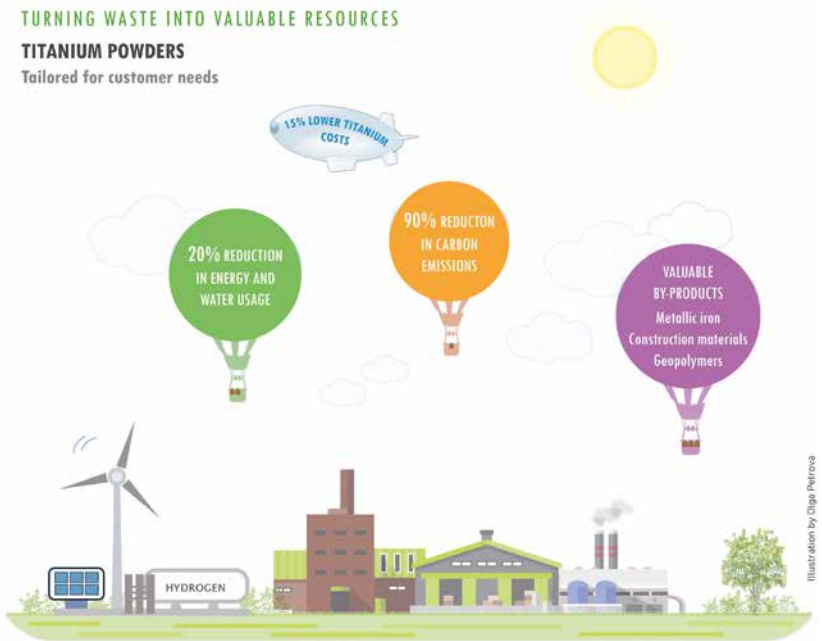
Unlocking titanium from Europe's metallurgical residues

Europe is a key consumer, but also a net importer of titanium. Europe's import-to-export ratio of titanium products (ingots, bars, sheets, tubes) is 6:1, the largest share. For unwrought titanium, such as sponge for wrought titanium products, the ratio is as high as 10:1. Therefore, in January 2025, the European Commission's Joint Research Centre (JRC) Science For Policy Report, recommended "securing a sustainable titanium ecosystem".

The present geopolitical situation clearly illustrates the dependency of European industries on titanium and its alloys and products. Russia, a key player, holds about 13% of the world's market share in titanium sponge. The Russian company VSMPO-AVISMA is the world's largest supplier with about 25% of the titanium market, ahead of Osaka Titanium (Japan) and UKTMP (Kazakhstan). Zaporozhye Titanium in Ukraine, producing 12,000 tonnes of titanium per year, ranks number six. Two thirds of titanium products serve civil applications. However, The titanium metal and alloy uptake by the defence sector is likely to increase significantly due to worldwide rearmament.

Titanium is exceptionally strong, lightweight, corrosion-resistant and biocompatible. Therefore, it cannot be substituted in most applications, although technologies are being developed to reduce its use.

Euro-Titan's impacts



Nanopowders of titanium oxides, metal or alloys are indispensable in the aerospace, automotive, medical and chemical sectors. Moreover, new titanium alloys are currently being developed for the renewable energy sectors, such as offshore wind turbines and solar panels. An increasing market is 3D printing and powder metallurgy. Innovative applications, such as integration in metal organic frameworks (MOFs) or as cement additives for high-strength materials, are promising niche markets.

Titanium metal is conventionally produced through the "Kroll process", emitting about 10 tonnes of CO_2 per tonne of metal produced. It is also a high energy consumer with an average of 260 MJ per kilo of metal.

Europe is an important producer of aluminium and TiO_2 and a major aircraft manufacturer. By-products from alumina (bauxite residues (BR) and TiO_2 production (TIR)), and end-of-life-aircraft parts (scrap) provide long-term resources for producing titanium metal and alloys in a circular model while reducing dependency on imports. BRs and TIRs are abundantly and continuously available in Europe.

Globally, about 150 million tonnes of BR are produced per year, a figure estimated to increase to about 200 million tonnes by 2050. Europe produces some 7 million tonnes of BR per year, and currently stockpiles around 250 million tonnes of BR. The BR currently being used by EURO TITAN comes from the Alumina Ltd. plant, Zvornik (Republic of Srpska, Bosnia and Herzegovina). The plant produces about 400,000 tonnes of BR per year at about 50 wt.% Fe2O3 and 5 wt.% TiO_2. BR, which is highly alkaline and toxic, must be neutralized at high cost and under particular conditions prior to disposal.

TiO_2 is mainly produced through sulphate and chloride processes, which differ somewhat regarding their primary ore feed. TiO_2 production is expressed as nameplate TiO_2

The Alumina Ltd, Plant Zvornik, Republic oF Srpska, Bosnia-Herzegowina where demonstration activities will be performed.
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capacity, which globally amounts to about 7.5 million tonnes for both processes combined. In Europe, the annual production of TiO_2 is estimated to be in the region of 1.5 million tonnes. Exact recent production data are difficult to obtain. Furthermore, markets and other constraints can cause the run rate to deviate substantially from the nameplate capacity. In Europe, the amount of TIR available for titanium powder extraction can be roughly estimated at 20–40 wt.% of the TiO_2 production, or roughly 0.3–0.6 Mt per year. TIRs are a factor 4 to 10 richer with 20 to 50 wt.% TiO_2 compared to BR (4–11 wt.% TiO_2). In both processing routes, untreated TIRs are highly acidic, rich in sulphates or chlorines, and must be neutralized prior to marketing, waste management and disposal.

The Horizon Europe project EURO TITAN (N°101135077, https://www.euro-titan.eu/) is a breakthrough contribution to reshoring titanium processing and improving titanium recycling from waste streams.

EURO TITAN will provide tailor-made titanium powder products, metallic iron and construction materials through decarbonized, flexible and modular processing, reducing carbon emissions by 90%. The required energy will be partially provided by renewable resources (wind, solar), leading to an approximately 20% reduction in fossil energy. Water consumption can also be reduced by a further 20% through recycling. Furthermore, our integrated data-driven operation will optimize individual process steps in real time.

The EURO TITAN project upscales and combines decarbonizing process steps via the use of green hydrogen pyrometallurgical technologies. The resulting slag, containing up-concentrated titanium, is further enriched using physical, physicochemical, and hydrometallurgical processing. The final products are titanium-based nanopowders.

During the first 15 months, upscaling experiments were mainly concerned with BR. Subsequently, TIR tests were started and compared with those from BR. In the same line, conventional experiments were performed to benchmark EURO TITAN's innovative low-carbon processing routes and use the data for LCA and business modelling.

Carbothermic reduction was performed on BR at 1600°C in an electric arc furnace to remove iron by smelting, followed by magnetic separation. Leaching of this slag in an autoclave at gradually optimizing parameters achieves the highest yield of titanium, as titanium oxysulphate while avoiding silica gel formation. The maximum titanium leaching efficiency of 95% was reached at 150°C at 5 mol/l of sulfuric acid and 9 bar oxygen in 2 h. High-pressure conditions suppressed silica gel formation during leaching. TIR from sulphate processing was directly leached without prior thermal treatment under the same conditions. However, significantly lower titanium and iron extraction rates were obtained.

The high iron oxide contents of BR and TIR are an important raw material but also interfere with the extraction of titanium. In the EURO TITAN project, iron is separated and transformed into crude iron while producing a highly concentrated titanium slag.

Two reduction processes are being investigated in EURO TITAN:
Direct reduction with H_2 (1a) and H_2 plasma smelting reduction (HPSR) (1b). After direct reduction, iron can then be separated by magnetic or density separation. Both approaches, as well as HPSR, produce slag with a high titanium content for further processing (BAM, MPI für Eisenforschung).

Subsequent leaching of Ti and Al at high oxygen pressures with sulfuric acid (5 mol/L) at 150°C from the slag reached 93.21% for Al and 84.56% for Ti extraction. The assisted ultrasound leaching of slag was less selective. Using sulphuric acid under atmospheric pressure resulted in lower leaching efficiency of titanium of 54% and silica gel was formed.

In 2024, the Technical University of Clausthal Zellerfeld (TUC) up-concentrated titanium-bearing phases from silicon-bearing light phases in both residues via density separation using a falcon concentrator and a wet shaking table after direct H_2 reduction and H_2 plasma reduction. Physical enrichment processes had the advantage of enhancing recovery rates while significantly decreasing chemical consumption due to the separation of the reactive portion of the material, thus contributing to the circular economy concept.

Titanium dioxide (TiO_2) powders are generally tailored to achieve specific particle sizes, shapes and purity levels using sol-gel processes, hydrothermal synthesis, electrochemical deposition and/or mechanical milling.

EURO TITAN synthesizes titanium-based powders from titanium oxysulphate using Ultrasonic Spray Pyrolysis (USP) technolo-

gy, a novel method that produces droplets. It is cost-efficient in continuous operation at high deposition rates and covers large surface areas. The average size of the droplets produced is typically less than 5 µm at low in-flight speeds. EURO TITAN produced titanium oxide from titanium oxy sulphate using ultrasonic spray pyrolysis under decreasing oxygen content at temperatures ranging from 700 to 1300°C. These titanium powders are composed of spheres of varying sizes ranging from nanometres to submicrons.

Depending on customer needs, EURO TITAN can tailor these powders. Additionally to titanium oxide powders, titanium metal and Ti-Al-based alloys will be produced using molten salt electrolysis and aluminothermic reduction, respectively

EURO TITAN has established a scalable data infrastructure for titanium-based powder extraction by integrating real-time analytical tools including LIBS for inline chemical monitoring and improved quality control. A big data platform is set to integrate life cycle assessments with industry forecasts and decision analysis to enable predictive process optimization. Anomaly detection combined with machine learning and reinforcement learning techniques will provide capabilities for continuous monitoring and process performance optimization. Real-time insights will be delivered through user-friendly dashboards as data architecture development receives collaborative input from partners of data collected per process and sensor data.

EURO TITAN is clustering with the Horizon Project "REPTIS". Workshops and panel discussions are planned for the European Powder Metallurgy Conference being held in Glasgow in September 2025. We meet regularly with our advisors, ELEMENTS22 and the European Powder Metallurgy Association (EPMA) to update customer needs.

The design of the plant and the demonstration are planned for 2027 at the Al-Doo Aluminium Production Plant (Zvornik, Republic of Srpska, Bosnia-Herzegovina) and at CIME-ORANO for TiO_2 residues (Bessines, France).

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References are available on request.

Euro Titan's process route