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MOZART

MOZART CONNECTING THE DOTS

FINAL ISSUE

MOZART Project: 48 Months of Innovation

INSIDE THIS ISSUE

Explore the final results of our 48-month journey, from AI-optimized molecular design to the successful pilot-scale production of sustainable Ni-nanocomposite coatings

A Remarkable Journey: 48 Months of Innovation

From a Bold Vision to Industrial Reality

The MOZART project was launched with a clear and ambitious goal: to revolutionize the European surface finishing industry by providing a safe and sustainable alternative to hard chromium. Today, as we conclude our 48-month journey, we stand proud of a project that has successfully bridged the gap between advanced digital design and pilot-scale industrial production.

We started from the molecular level, using AI to design safer chemical alternatives, to the factory floor, where we validated new coatings on real-world components like piston rods and gears. MOZART has proven that performance and sustainability can go hand-in-hand, achieving a high 70% reduction in global warming potential while maintaining the extreme hardness and low friction required by modern industry.

Our Collective Success: A Sincere Thank You

This achievement is the result of an extraordinary collaboration across all disciplines. We want to extend our deepest gratitude to every partner, researcher, and technician who contributed to the MOZART consortium.

- To our Technical Partners: Thank you for pushing the boundaries of Safe and Sustainable by Design (SSbD), AI, plating, nanoparticle monitoring, and material science.

- To our Industrial & Testing Partners: Thank you for your rigorous validation and for bringing these innovations to a TRL 5 pilot scale.

- To our Impact & Legacy Team: Thank you for ensuring the project's success reaches far beyond the lab. You have translated complex data into the accessible c-safe Decision Support Tool, while serving as the vital bridge to the outside world ensuring our breakthroughs were communicated effectively across the industry and paving the way for the future market uptake of MOZART solutions.

THE MOZART PROJECT was more than just a series of work packages, it was a shared commitment to a greener, safer European manufacturing landscape and a collective effort to ensure these innovations reach the hands of those who can make a difference.

Click here to see some highlights of our Project

WATCH VIDEO

MOZART in Action at Coatings 2026

From 20–22 April 2026, our project actively contributed to the Coatings 2026 conference in Athens, Greece, with the presentation of two scientific posters:

- Financial Evaluation of Advanced Gear Coatings
- Decision Support Tool for Selection of SSbD Coating Alternatives

Both posters were developed by AXIA Innovation GmbH, showcasing cutting-edge approaches to sustainable and cost effective coating solutions.
The three-day event provided an excellent platform for great discussions, valuable feedback, and inspiring exchanges with the wider coatings community.

For more information and to see images of the event, please click here.

Designing Safety at the Molecular Level

The foundation of a sustainable coating process begins long before the first metal is plated. One of the most significant challenges in the MOZART project was finding a safer alternative to boric acid, a traditional buffering agent that, while effective, no longer meets the stringent sustainability and safety requirements of the modern industry.

Generative AI: The Search for a Better Molecule

To solve this, AIMEN pioneered an AI-driven approach to "Inverse Molecular Design." Instead of the slow, traditional trial-and-error method in a lab, the team utilized a Conditional Variational Autoencoder (CVAE), a powerful generative machine learning model.

By training this AI on thousands of acid-molecule data points, the model learned to generate new molecular structures. To ensure these new candidates were chemically valid, the team compared different molecular "languages" (SMILES vs. SELFIES), finding that the SELFIES-based model offered the highest robustness for creating realistic, sustainable chemical alternatives.

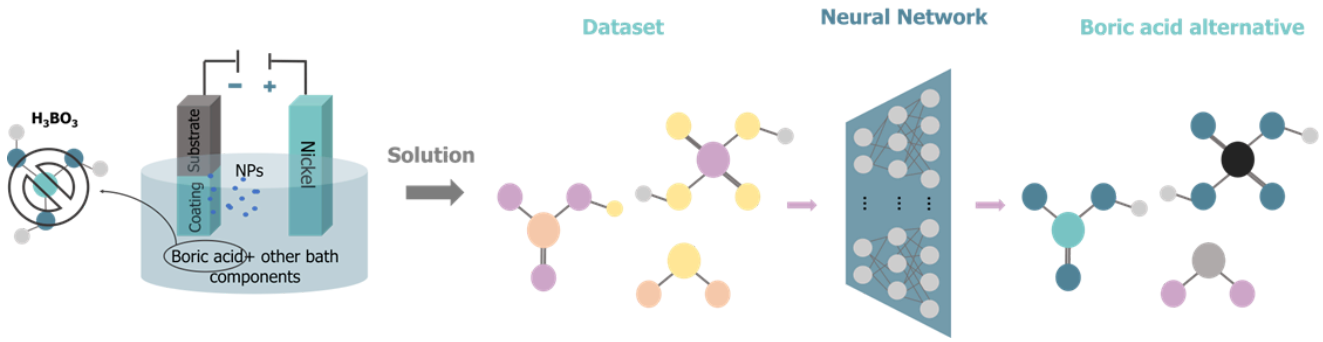

Figure 1: Illustration depicting the primary goal of the study

Optimization through Evolution

Finding a new molecule is only half the battle; it also has to behave like the original. AIMEN implemented Genetic Algorithms, a method inspired by natural evolution, to search through the vast "chemical space." By using advanced metrics like the Tanimoto coefficient and Euclidean distance, the AI narrowed down thousands of possibilities to find the most promising candidates that match the performance of boric acid without its environmental drawbacks.

The Impact: Accelerating SSbD

TThis work marks a significant milestone for the Safe and Sustainable by Design (SSbD) framework. It proves that combining Generative AI with evolutionary optimization can:

- Drastically accelerate the exploration of safer chemicals.
- Minimize laboratory waste by focusing only on the most viable candidates.
- Ensure high performance by matching the physical properties of traditional materials.

"The MOZART project demonstrates that AI is not just a digital tool, but a vital catalyst for the green transition in material science." AIMEN Team

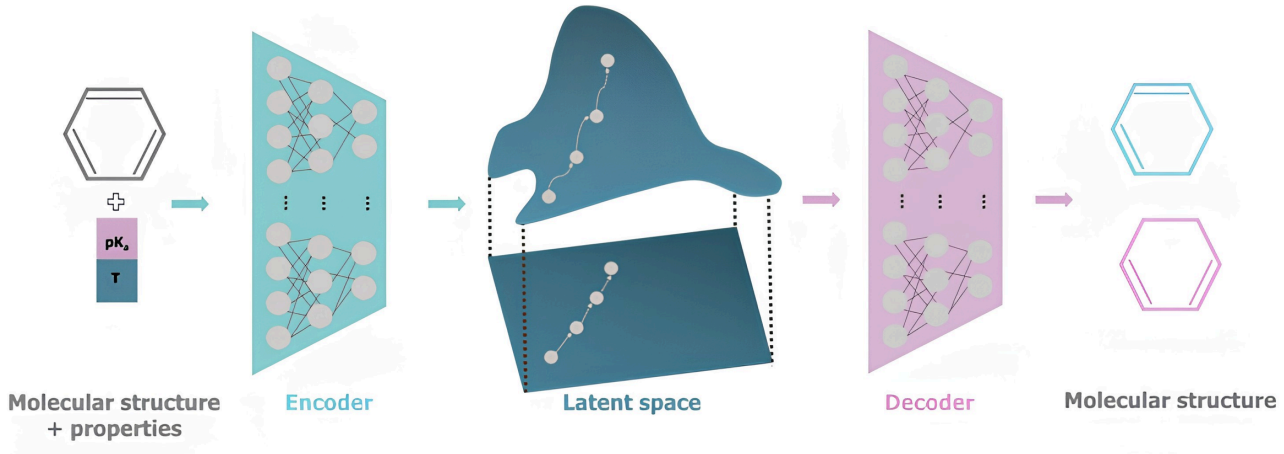

Figure 2: Representation of a Conditional Variational Autoencoder (CVAE)

2. Pilot Scale Success

From Laboratory Innovation to Industrial Reality

The transition from molecular design to industrial application is where innovation meets the factory floor. In the MOZART project, this meant developing a REACH compliant chemistry and proving its performance on a 250-liter pilot scale under continuous real-time monitoring.

The Eye of the Process: Real-Time Monitoring by Brave Analytics

To ensure the stability of nanocomposite coatings, it is essential to precisely control both the concentration and size of particles in the electroplating bath. Brave Analytics successfully developed, installed, and validated an automated online OF2i® monitoring system at the Creative Nano pilot facility in Greece.

This technological breakthrough included:

- Precision Down to 50nm: Refined trajectory models now enable reliable measurement of particles as small as 50nm (improved from the previous 100nm limit).
- Complex Characterization: The system was extended to simulate and measure non-spherical particles, agglomerates, and complex suspensions, essential for industrial coating baths.
- Scientific Excellence: The versatility of the technology, including Flow and Correlative approaches like Raman spectroscopy, was highlighted in high-impact journals such as Nano Letters and Nanophotonics.

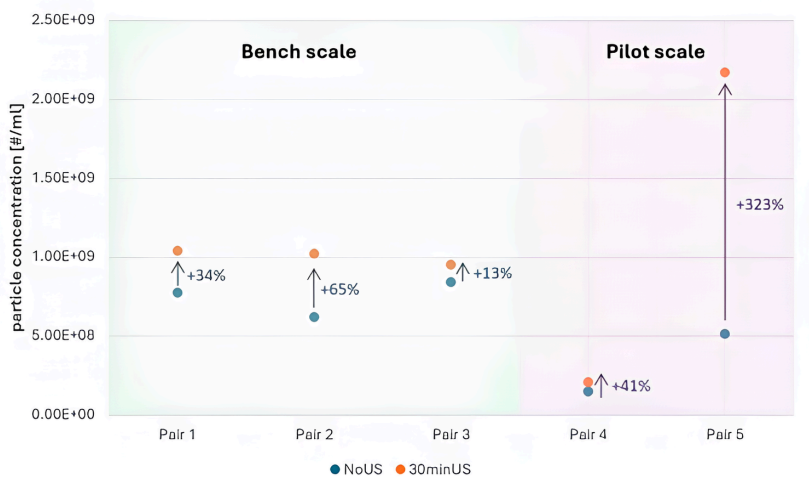

Figure 3: Pilot-scale validation: Ni/SiC and Ni/Gr coatings on industrial components

2. Pilot Scale Success

The Industrial Breakthrough: Creative Nano (Cnano)

At Creative Nano, the MOZART concept progressed from laboratory development to pilot-scale industrial implementation. Over 48 months, the team systematically developed and optimized a boric acid-free Ni electrolyte as a sustainable alternative to conventional coating chemistries.

Key Achievements at Pilot Scale (TRL 5):

- Superior Performance: Using Silicon Carbide (SiC), the team produced piston rods with Vickers hardness exceeding 1000 HV, matching or exceeding the performance of traditional hard chromium.
- Low-Friction Solutions: By incorporating Graphene (Gr) and WS_2, the project achieved advanced coatings for gear components with a coefficient of friction (CoF) consistently below 0.15.
- SSbD Compliance: The pilot line was upgraded to be fully Safe and Sustainable by Design, ensuring the process is safe for workers while delivering high-end industrial performance.

Validation through Collaboration

This chapter represents a key milestone in MOZART's industrial validation. Cnano provided the pilot-scale production environment and continuous feedback on HEBM-produced dispersions, while Brave Analytics enabled real-time monitoring under representative industrial conditions. Together, these activities demonstrated the feasibility and market readiness of sustainable coating solutions.

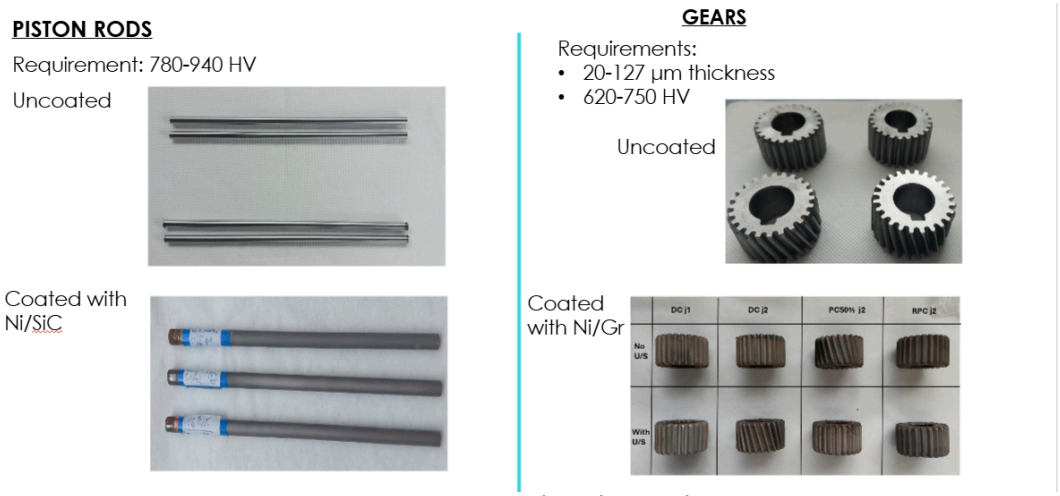

Figure 4: MOZART piston rods and gears demonstration

3. Proven Performance

Validating the Future of Surface Finishing

After 48 months of rigorous research, the MOZART project has moved beyond proof-of-concept to deliver verified, high performance results, by combining sustainable chemistry with advanced manufacturing techniques.

Technical Excellence: Hardness & Friction

The final validation of the MOZART coatings on industrial demonstrators confirms that our Ni-matrix nanocomposites meet the most demanding engineering standards:

- Extreme Durability: Our Ni/SiC coatings reached Vickers hardness levels exceeding 1000 HV. This matches the performance of traditional hard chromium, ensuring that components like piston rods are protected against extreme wear.
- Advanced Lubrication: By integrating Graphene (Gr) and WS_2, the project achieved a coefficient of friction (CoF) consistently below 0.15. This makes it an ideal solution for complex gear components where low friction is critical for energy efficiency and lifespan.

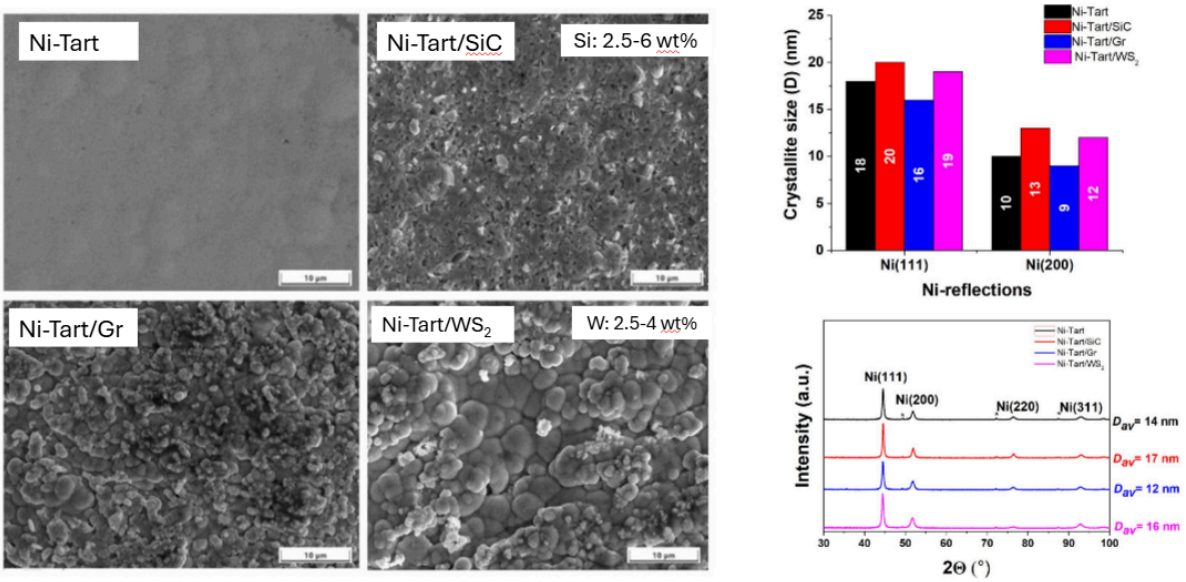

Figure 5: MOZART evolution: Scaled-up coatings for gears and piston rods

Environmental Impact: A 70% Victory

The performance of MOZART isn't just measured in hardness, but in its footprint. Through the removal of toxic substances and the optimization of the plating process, we achieved:

- Waste Reduction: A massive ~70% reduction in solid waste generation and sludge formation compared to traditional methods.
- Safety First: The total elimination of Boric Acid and Hexavalent Chromium, ensuring full compliance with REACH regulations and a safer environment for industrial workers.

70% **Waste Reduction**	MOZART	**1000 HV** **Hardness**

Market Readiness: The data generated by NTUA and Creative Nano highlights the potential of these coatings as promising sustainable alternatives for future industrial implementation in the European manufacturing sector.

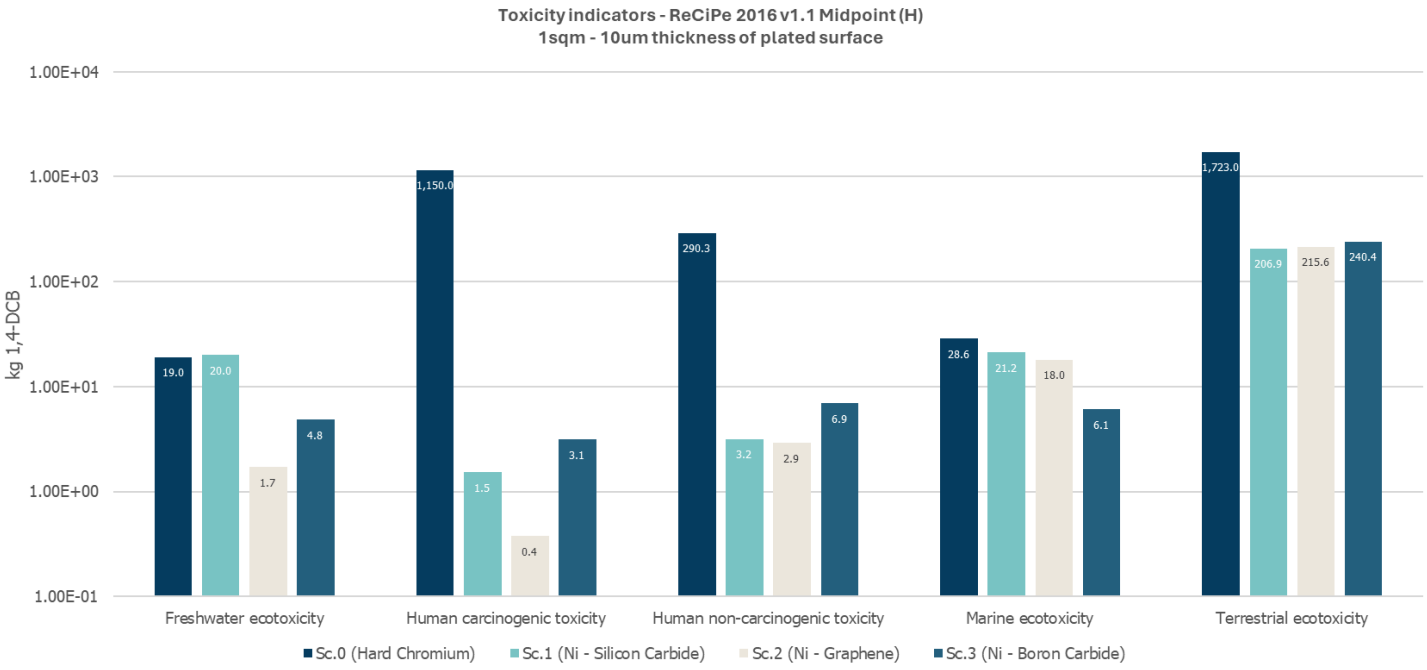

Figure 6: Toxic indicators based on NTUA Results

4. Environmental Impact

The 70% Reduction: Quantifying Success

Through rigorous Life Cycle Assessment (LCA) and pilot-scale monitoring, the project demonstrated that switching to MOZART's boric acid-free chemistry provides a massive leap in environmental performance:

- Waste Management: We achieved a ~70% reduction in solid waste generation and hazardous sludge formation compared to conventional hard chromium plating.
- Toxic-Free Chemistry: The total elimination of Boric Acid and Hexavalent Chromium (Cr6+) ensures the process is fully REACH-compliant, removing significant health risks for factory operators and reducing ecotoxicity.
- Resource Efficiency: The use of optimized pulse current (PC) regimes and more stable electrolytes has led to improved current efficiency (exceeding 90%), translating to lower energy consumption per coated part.

The Circular SSbD Roadmap

The project didn't just produce a better coating; it produced a validated methodology. As illustrated in our Circular Roadmap, every step of the process, from the AI-driven molecular design of buffering agents to the real-time nanoparticle monitoring at 50nm, was designed to be inherently safe.

This roadmap serves as a blueprint for the European surface engineering industry, proving that REACH compliance is not a barrier to innovation, but a catalyst for it. The data confirms that our three primary scenarios, Ni-Silicon Carbide, Ni-Graphene, and Ni-Boron Carbide, all outperform traditional methods in sustainability without sacrificing industrial performance.

The c-safe Decision Support Tool

As the MOZART project concludes, we leave the industry with a powerful digital asset: the c-safe tool. Developed by AXIA Innovation GmbH, this web-based platform serves a centralized platform consolidating project outcomes and decision support functionalities, ensuring that our research doesn't just sit in a report but becomes a practical resource for manufacturers.

The development of the c-safe tool was made possible through a wealth of diverse data provided by our consortium. Polimi and Cnano contributed vital technical data on stamping dies, gears, and piston rods, while NTUA supplied the comprehensive environmental and LCA datasets. These were further enriched by the UoB, which provided the foundational principles of SSbD. By synthesizing these technical, environmental, and safety pillars into one interface, the c-safe tool stands as a robust, data driven resource for industrial decision making.

Data-Driven Decision Making

The c-safe tool is a sophisticated Decision Support System (DSS) designed to simplify the transition to sustainable coatings. It allows users to perform high-level Scenario Analysis by integrating technical, environmental, and economic data into a single, user-friendly interface.

- Multi-Criteria Assessment: As seen in the tool's dashboard, it utilizes a structured methodology to rank coating alternatives. It evaluates key indicators, such as Global Warming Potential (GWP), Human Toxicity, and Resource Use against traditional industrial performance metrics.
- Optimization & Customization: * The Optimization Workflow: Helps manufacturers rank and identify the best predefined coating scenarios (e.g., Ni-SiC or Ni-Graphene) based on their specific company priorities.
    - The Customization Workflow: Allows users to define their own specific coating formulations and receive an instant sustainability "health check" based on the project's data.

Validating the Future

The tool has been successfully validated through three real-world replication cases from the surface finishing industry. By digitizing the SSbD framework, c-safe ensures that the MOZART legacy continues, providing a clear, data backed roadmap for any facility looking to replace hard chromium with a high-performance, eco-friendly alternative.

Figure 7: Overview of the c-safe tool

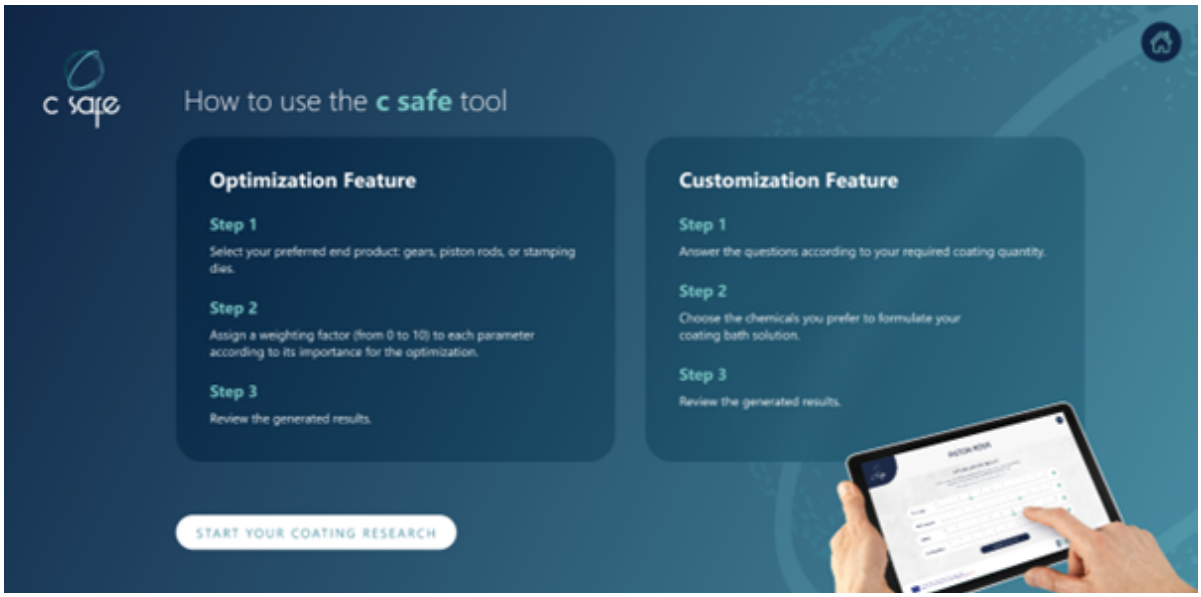

Figure 8: How to use the c-safe tool

METAL MATRIX NANO-COMPOSITE COATINGS UTILIZATION AS ALTERNATIVE TO HARD CHROMIUM

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