



TRANSFORMING AVIATION



Sustainability Report
MTU AERO ENGINES AG
BUSINESS YEAR 2022

THE TOP PRIORITY IN AVIATION

Product quality and flight safety

Safety first—for us, safe flight operation is way more than just a legal requirement. In aviation, it is the highest priority. That’s why we place high demands on quality and safety—not least because reliable and high-quality products are our trademark.



MTU stands for sustainable quality management and pursues the vision of zero defects.

Quality and safety are of paramount importance in aviation and the conditions are strictly regulated. And complying with legal requirements concerning safety is subject to strict monitoring by the relevant authorities. This is mirrored in the high importance MTU places on product quality and flight safety. The company must comply with the legal requirements imposed upon it as an organization that develops, manufactures and maintains products, parts and equipment for the aviation industry. These include aviation-authority licenses, approvals and certifications as well as safety and environmental requirements as legally mandated by regulatory authorities. Through stringent quality standards, we ensure that these are implemented across the Group and at all levels of the value chain in accordance with the law, thus adding value for our customers and partners. Safe mobility solutions play an important role in the sustainable development of both society and the economy. Our vision is Zero Defects. In this, we stand for sustainable quality management.

A Group-wide [integrated management system \(IMS\)](#) ensures compliance with laws and internal regulations and clearly assigns responsibilities within the company. One principle of the IMS policy is that “safety takes priority in what we do.” The quality framework is enshrined in a management manual that is binding for all employees and managers across the Group. The company’s dedicated quality department, Corporate Quality, is directly subordinate to the Chief Operating Officer (COO) and reports quarterly to the full Executive Board on quality aspects and flight-related incidents. Through independent, accredited external auditors, we regularly validate and certify our IMS. MTU Safety Management in accordance with the [International Civil Aviation Organization \(ICAO\)](#) standard is part of the IMS and defines how to handle safety-related air-traffic events. Appropriate organizational structures and responsibilities, such as a Flight Safety Board and a Flight Safety Manager, have also been established.

High quality standards together with product safety and reliability are enshrined in the MTU Principles as key corporate objectives. MTU's quality vision for 2025 also aims at error-free quality and product safety in flight, as well as high customer satisfaction.

Focus on the entire lifecycle of a propulsion system

We take into account all safety and environmental requirements of regulatory authorities in the early stages of developing new engines for later use, and compliance must be documented as part of the certification process. We employ a comprehensive testing program involving test rigs and test series to validate the safe flight operation of our products. This includes safe operation during a hailstorm or a bird strike (following a bird ingestion event) and complying with strict limits on pollutants and noise emissions. MTU components frequently exceed aviation authority requirements, because our customers demand high standards when it comes to fail-safe operation and eco-efficiency. In addition, our manufacturing and maintenance of engine parts and modules meets all required occupational safety and climate protection standards.

We examine our engine modules for their impact on the environment, health and safety throughout their development, production and operation lifecycles. Accordingly, we cover all major stages of a product's service life. The key to our continuous progress is the development phase.

We use only fault-free and clearly identified components that have been approved by the appropriate aviation authority and are based on approved development documentation. They must also have been produced or maintained in compliance with aviation regulatory processes by a company officially authorized to do so.

BREACHES OF COMPLIANCE



0

We refuse to compromise on quality. What does that mean? In 2022, we didn't record a single breach of legal or internal compliance regulations with regard to the quality and safety of our products.

The aviation sector has strict rules governing documentation in order to verify the airworthiness of components and engines. There must be no gaps in documentation for the product's entire service life. We hold our suppliers to the same standards and audit them regularly to ensure compliance. To ensure quality and safety requirements are upheld, we have implemented comprehensive monitoring and testing processes along the entire value chain. Safety-critical components (engine components are categorized into various safety classes) are subjected to particularly rigorous testing to verify their technical quality. Strict requirements also apply to materials. Since fail-safe materials are a basic prerequisite for aviation safety, all engine components, including all materials we use, must be approved by the aviation authorities after undergoing extensive test series.

In the reporting year, there were no breaches of statutory regulations regarding compliance in connection with the purchase or operation of our products that resulted in a fine, sanction or warning for MTU.

Sustainable quality management

At MTU, we develop and refine our quality system together with our standards and regulations on an ongoing basis. This involves applying the ideas that emerge, for example, from collaboration in the [Aero Engine Supplier Quality Group \(AESQ\)](#) or from regular exchanges of experience and information among our quality managers in the aviation industry. Continuous development primarily concerns MTU's body of rules and regulations, its internal quality reporting system and especially the digitalization of quality processes.

We include all our employees in our high quality standards. Managers and employees receive site-specific training on quality issues. All employees receive IMS training. In addition, we are committed to a positive no-blame culture at MTU, characterized by openness and collaboration, and provide ongoing training on this subject.

We have customers and authorities conduct regular internal and external audits of quality issues to ensure that the uniformly high standards within the company are adhered to and that they comply with the regulatory requirements.

Through various initiatives to continuously improve product and process quality, we are supporting our business growth following the pandemic-related crisis:

- The Passion for Quality campaign, part of our quality vision, focuses on making employees' contribution to quality visible in all areas of the company and raising quality awareness (Munich, Hannover, Berlin, Rzeszów, Vancouver sites)
- The MRO network development project aims to standardize core processes in commercial engine maintenance across all MRO sites on the basis of best practices
- With the AS13100 Implementation project, MTU is implementing new industry-wide standards jointly developed in AESQ as well as new requirements in quality management (Munich, Rzeszów)

Further increase customer satisfaction

A high level of product quality and safety is crucial for customer satisfaction and our competitiveness. As in previous years, "We increase the satisfaction of our customers" remained an overarching corporate objective for 2022. The secondary objectives were defined in more concrete terms, with the aim of ensuring that MTU remains an attractive partner for its stakeholders through the high performance and quality of its products and services. IMS, our certified integrated management system, supports us in ensuring customer satisfaction, process orientation and continuous improvement in all phases of development, production and maintenance. IMS takes into account, for example, the requirements of the standards ISO 9001, EN/AS9100, ISO 14001/EMAS and ISO 45001, and serves as a model approach in the aviation industry.

We set great store by customer complaints as an indicator of their satisfaction with the quality of MTU products. We follow up and analyze all customer complaints relating to products delivered in substandard quality. Appropriate measures are then defined and implemented so as to permanently eliminate the cause of the defects. Success of these measures is closely monitored. Customer complaints are assessed at the site level. At two sites, the number of customer complaints increased compared to the previous year; for the majority of sites, it decreased or remained constant.

Taking valuable feedback on board

MTU Maintenance offers maintenance and additional services for aircraft engines and industrial gas turbines, and is thus active in the end-customer business. Direct interaction with customers, specifically airlines, leasing companies and energy producers, forms the basis of customer care. Once a quarter, we use an IT-based “voice of the customer” module to measure current customer satisfaction levels for our Hannover, Ludwigsfelde and Vancouver sites and for all main products. Each customer has the option of providing feedback about product quality, service, logistics and contractual terms. We use this valuable feedback to identify areas for improvement and initiate measures accordingly. Doing so allows us to continuously optimize our performance, increase customer satisfaction and stay competitive. In addition, MTU Maintenance Lease Services runs its own system for measuring satisfaction in the engine leasing and asset management business. We want to engage more closely with our customers on sustainability issues and will use the Voice of the Customer tool to do so. Integration is planned for 2023.

[More information about dialogue with our stakeholders](#)

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TOWARD ZERO EMISSIONS

Climate impact of aircraft engines

With its innovative propulsion products, MTU is often a technology pacesetter. We are also currently hard at work on new generations of propulsion that are still more sustainable. Never before have we had such forward-looking concepts as we do today.



We presented this model of the Water-Enhanced Turbofan (WET) at the ILA 2022 in Berlin. MTU's propulsion concept reduces fuel consumption, all emissions that have a negative climate impact, and contrail formation.



Zero emissions—this is MTU's vision and overall goal when it comes to reducing the climate impact of propulsion systems in flight operations. By taking on responsibility for climate action, we want to help achieve the goals laid out in the Paris Agreement, which serves as a focal point in technology development. MTU bases its own objectives on the EU Green Deal, which is derived from the Paris target of a 1.5 degree increase and aims to achieve climate neutrality by 2050. In addition to evolutionary and revolutionary propulsion concepts, our Clean Air Engine technology agenda, or Claire, also includes a quantification of the potential in reducing climate impact and energy consumption. We want to achieve these goals in three stages.

The focus is no longer on CO₂ emissions alone, as was previously the case, but on the overall climate impact of air traffic. That includes non-CO₂ effects, triggered mainly by emissions of nitrogen oxides and the formation of contrails. In response to this paradigm shift, MTU realigned its Claire agenda in the reporting year and presented it to the public at the ILA airshow. We have set out time horizons, targets and implementation options in Claire, taking into account the three application areas of aviation—short-haul, medium-haul and long-haul.

Clean Air Engine – Claire

With our Claire technology agenda, we are taking off into a new future of aviation. Emissions-free flight—a vision that drives us.

[MORE IN OUR SPOTLIGHT](#)

The aviation industry is characterized by long product cycles. As a rule, aircraft engines spend up to 30 years in service before they are decommissioned. Climate goals have a long-term perspective and are established in memoranda of understanding by stakeholders (airlines, aviation industry, research, aviation authorities), such as Fly the Green Deal, Europe’s vision for climate-neutral aviation. If they are to be effective across the board in 2050 and help in achieving climate neutrality, propulsion products that enable climate-neutral flight must be brought to market well before then. That is why we are ramping up the development of completely new propulsion concepts that go above and beyond the conventional gas turbine. For these revolutionary engine architectures, we collaborate with partners from industry, science and research, such as Bauhaus Luftfahrt or the German Aerospace Center. In parallel, MTU is working to enhance existing propulsion systems, such as the highly efficient geared turbofan (GTF) together with Pratt & Whitney, and to couple these with sustainable fuels.

Fast Facts: The geared turbofan

EVERY



20

seconds, a GTF takes off somewhere in the world.

MORE THAN



3

billion liters of kerosene were saved over 18 million flight hours.

MORE THAN



10

million metric tons of CO₂ were thus also saved.

Compared to the previous engine generation, as of: Q1 2023, according to information from Pratt & Whitney

Evolutionary and revolutionary concepts for climate-neutral aviation

Together with our partner Pratt & Whitney, we are offering a highly efficient propulsion concept: the GTF engine family, used in modern narrowbody aircraft (A320neo as well as Airbus A220 and the Embraer E-Jet E2 family). Compared to the previous generation, engines of the GTF family reduce energy consumption and CO₂ emissions per trip by 20% each. Flight testing of the GTF Advantage, a technologically enhanced GTF version for the A320neo family, began in the year under review.

This engine family has become a major business success and measurably reduces the burden on the environment: This first generation has already enabled airlines to save more than 10 million metric tons of CO₂ in 18 million flight hours (as of Q1 2023, according to information from Pratt & Whitney). It also brings significant improvements in terms of NO_x emissions, which are 50% lower than those of its predecessor.

To exploit the GTF's full potential, MTU is working with Pratt & Whitney to prepare the next generation of the product. Many of the technologies required for this are being developed as part of the German Federal Aviation Research Program (LuFo). In its second round, LuFo approved several collaborative projects on new compressor and turbine technologies in 2022. Numerous drafts submitted by MTU were also approved during the draft phase of the third LuFo round. The main focus here will be on improving component efficiencies as well as materials and digitalization.

Sustainable aviation fuel



Sustainable aviation fuel (SAF) will play a major role in efforts to achieve climate neutrality. SAFs can be used in admixtures of up to 50% as a “drop-in” fuel—i.e., without the need to adapt the aircraft or engine. MTU maintains an ongoing dialogue with relevant stakeholders and participates in studies to support the introduction of SAF; for example, through its membership in the Aviation Initiative for Renewable Energy in Germany (aireg e.V.), an association of airlines, manufacturers and research institutions. An aireg study on sustainable fuels published in 2022 with the involvement of MTU highlights the great potential of SAF.

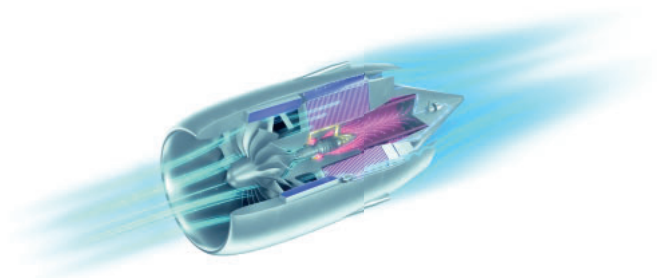
A feasibility study on electricity-based SAF was completed in 2022 as part of the CleanTech in Aviation working group, of which MTU is a member and which is chaired by the Bavarian Ministry of Economic Affairs, Regional Development and Energy. The working group aims to set up a power-to-liquid plant in Bavaria for the production of SAF.

From evolution to revolution – We go one step further

Our WET concept: Wet combustion thanks to the Water-Enhanced Turbofan

As outlined in our Claire agenda, purely evolutionary technology development will not be enough to achieve climate neutrality by 2050. Revolutionary propulsion concepts are needed. MTU's favored technology is the Water-Enhanced Turbofan (WET). Utilizing thermal energy from the exhaust gas stream, it uses a steam generator to vaporize water, which is then injected into the combustor. The water for this purpose is extracted from the exhaust gas by means of a condenser. "Wet" combustion of this kind massively reduces nitrogen oxide emissions, while also substantially decreasing fuel consumption, CO₂ emissions and the formation of contrails.

CLEAN AVIATION: THE SWITCH PROJECT



→ [To the press release](#)

SWITCH stands for Sustainable Water-Injecting Turbofan Comprising Hybrid-Electrics. The project focuses on combining two revolutionary technologies: MTU's Water-Enhanced Turbofan concept, and hybrid-electric propulsion system components. Work centers on Pratt & Whitney's Geared Turbofan™ engine. The goal is to demonstrate a 25% reduction in fuel consumption and thus also of carbon emissions. Furthermore, the project aims to reduce nitrogen oxides and particulate emissions as well, thus minimizing overall climate impact.

Flying Fuel Cell (FFC): Virtually emissions-free

Another revolutionary propulsion concept is the full electrification of the powertrain. The MTU concept is called the Flying Fuel Cell™ (FFC) and is set to be deployed soon on short-haul routes in regional air traffic. This propulsion system does not produce any emissions of CO₂, NO_x or particulates; MTU has been able to win research support for this concept, particularly in the context of the third LuFo round—several project outlines for the development of an aviation-optimized system received positive responses.

Even if 2050 still seems a long way off, urgent action is required now, as aircraft development and product cycles are measured in decades. If we are to shape the future of aviation, a number of key developments must be set in motion today. MTU has embarked on this journey with its Claire technology agenda. In keeping with the MTU Principles: We shape the future of aviation—a green future.

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UNGC: [7](#), [8](#), [9](#)

REDUCING ENGINE NOISE AND EXHAUST GASES

Health impact of aircraft engines

As part of our product development, we are working to make aviation considerably quieter and cleaner. Our stated goals therefore include reducing aircraft noise and exhaust emissions to minimize the impact that our products—in the air and on the ground—have on people’s health.



Through our Clean Air Engine agenda, we are pursuing a reduction in aircraft noise emissions in addition to our targets for climate action. At our sites, we carry out noise measurements on our test stands.



We undertake to protect the environment; climate action is one part of this, but our endeavors go further still. With quiet and clean engine concepts, we can improve the situation for residents living near and around airports in terms of noise pollution and local air quality, thereby promoting society’s acceptance of air travel. As with our approach to climate action, we have established several pillars to anchor the issue of aircraft noise in the company. In our [global Code of Conduct](#), we commit to environmental protection and explicitly to reducing noise and exhaust emissions from aircraft engines. We want to set standards in this area, and we have formulated our goal accordingly. The MTU Principles also include the requirement to create products with lower noise and pollutant emissions under the heading “Environment & society.”

To receive certification from aviation authorities both aircraft and engines must meet noise and emissions limits set by the [International Civil Aviation Organization \(ICAO\)](#); in the past, these limits have been successively tightened. National aviation authorities are responsible for certification. Furthermore, at almost every airport in the world, the fees charged for takeoff and landing are dependent on the noise emissions of the aircraft model.

How is aircraft noise generated?

Aircraft noise is caused by both the engine and the aircraft itself. Noise during takeoff is largely due to the engine's fan and nozzles; during landing, the aircraft also adds to noise as a result of turbulence around the fuselage, wings and landing gear.

The core engine accounts for a relatively small proportion of aircraft noise.

In the certification of new aircraft models, noise is measured using a standardized process at three defined points and then cumulated. Aircraft noise has decreased continuously since the 1960s, by a total of about 17 EPNdB (effective perceived noise decibels; a specific unit for measuring the relative noisiness of aircraft) or about 70%.

Quieter flying: We are pushing for Europe's SRIA noise targets

With our technology agenda Clean Air Engine (Claire), we are pursuing not only climate action targets → [Climate impact of aircraft engines](#), but also targets for reducing aircraft noise emissions. Achieving future noise limits is one of the agenda's core elements. MTU's acoustics experts are involved in our projects at every stage of product development, from technology management to subsequent propulsion system design and optimization.

When developing future propulsion systems, we support the goals of the [European aviation industry and research sector's Strategic Research and Innovation Agenda \(SRIA\)](#), which calls to reduce noise to 65% of its 2005 levels by 2050. With the first-generation geared turbofan, which we developed together with our partner Pratt & Whitney and continue to manufacture, we have already significantly reduced aircraft noise emissions as part of Claire Stage 1. They are on average 15–20 EPNdB (cumulated over the three ICAO measuring points) below the current legally stipulated noise emission class, ICAO Stage 4. This equates to a reduction in the geared turbofan's noise footprint (spread of aircraft noise near airports) of 75% compared to the previous generation.

LESS AIRCRAFT NOISE



75 %

smaller noise footprint of our geared turbofan from Claire Stage 1 has significantly reduced the spread of aircraft noise in the sensitive area around airports. The geared turbofan already has over four million quieter flights to its name.

The geared turbofan from Claire Stage 1 has an architecture that harbors vast potential for further reducing noise compared to conventional turbofans. By making improvements to the latest generation, we want to achieve the SRIA goal of a 50% reduction in aircraft and engine noise emissions by 2035 (base year 2000).

According to the SRIA, new engine architectures are even to achieve a 65% drop in noise emissions by 2050 (base year 2000). Our efforts here include our new propulsion concept, the (hydrogen-powered) Flying Fuel Cell™, which can achieve massive reductions in noise because the fan is the powertrain's sole source of noise. It is set to be ready for short-haul routes by 2050.

New concepts pave the way for zero pollutants

In addition to contributing to climate effects and generating noise, air traffic also has an impact on local air quality at airports and in surrounding areas. The combustion process in aircraft engines produces pollutants in the form of nitrogen oxides (NO_x), carbon monoxide (CO), unburned hydrocarbons (UHC) and soot/particulate matter. In terms of the impact these have on health, NO_x and particulate matter emissions are the most significant. To obtain type certification, aircraft and propulsion systems must meet ICAO environmental standards. ICAO has defined limits for the levels of NO_x, CO, UHC and soot emitted by aircraft engines. All of the engines in which MTU holds a workshare meet the ICAO certification standards. In the meantime, compliance with standards for ultra-fine particulate emissions became a criterion for engine certification. Unlike with noise emissions, we have less scope to influence NO_x and particulate matter emissions and the health effects because the combustor is not part of our portfolio for commercial engine programs. We can make a difference here only indirectly by improving the efficiency of the engine. For example, with the geared turbofan we have succeeded in significantly reducing NO_x emissions, which are 50% lower than those of its predecessor. Sustainable fuels can also make a big difference in this regard. In initial tests, the German Aerospace Center (DLR) has shown that particulate emissions from combustion are significantly lower with sustainable aviation fuels (SAFs) than with conventional aviation fuels. Using hydrogen as a fuel reduces them even further.

REDUCTION IN NITROGEN OXIDES



80 %

Our new propulsion concept WET can significantly reduce pollutants. It works by injecting water into the combustor, which, based on what we know so far, can cut NO_x emissions by up to 80%.

Our development of revolutionary propulsion concepts, which is part of our climate action activities, also holds great potential for reducing pollutant emissions. Our Water-Enhanced Turbofan (WET) and Flying Fuel Cell (FFC) concepts can significantly reduce pollutant emissions or even avoid them altogether. The WET concept works by injecting water into the combustor, which, based on what we know so far, can cut NO_x emissions by over 80%. Hydrogen-powered fuel cells would actually emit nothing but water.

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INNOVATIONS FOR A SUSTAINABLE FUTURE

Research & development

We are a technology leader in aviation—and it is our extensive research work and high level of innovation that keep us in this top position. Our ideas and concepts aim to transform aviation. With our research and development work, we are playing a key role in realizing a sustainable future for aviation.



MTU employees introduced a new measurement technique in PW1100G-JM final assembly; this engine belongs to the highly efficient GTF family. At MTU, numerous experts work on creating innovations and new solutions for the future.



We are committed to the principle of integrated environmental protection, which takes a precautionary approach to how the company's products impact the environment and integrates insights from this into entrepreneurial decisions. This applies above all to our research and development work. In the technology and innovation process, our experts investigate environmental and societal driving forces for aviation and take them into account when defining MTU concepts and targets. We receive input for our analyses and stakeholder expectations through various channels as part of our stakeholder dialogue, which we conduct on an ongoing basis with all stakeholders. → [More about stakeholder dialogue](#)

Shaping the future sustainably with innovations

MTU manages technology development for future products using a multistage process. In the medium term, advanced product designs are created and technology requirements derived from them. And over the long term, pilot concepts are developed with the help of a technology radar, and the development of enabling technologies initiated. One example of an advanced product design is the next-generation geared turbofan; pilot concepts are the Water-Enhanced Turbofan (WET) and the Flying Fuel Cell. An Innovation Board regularly discusses all topics related to technology and innovation and initiates technology projects and studies. The technology steering committee (TLA) is responsible for MTU's technology roadmap and is regularly updated on its progress. During the reporting year, MTU realigned its Climate agenda, which was approved by the TLA and thus by the Chief Operating and Chief Program Officers. → [For more information, see Climate impact of aircraft engines](#)

The basis of this technology process is our culture of innovation, which we cultivate with a variety of initiatives. These include a Group-wide innovation management concept; the Inno Lab, our creative think tank; and Ideation Challenges, through which we gather and evaluate ideas from employees related to a specific field of innovation.

Innovation Day

Innovations don't just come out of the blue, but must be systematically developed and implemented toward a specific goal.

Our experts throw themselves into their work with great enthusiasm as they shape the future sustainably through their accomplishments. MTU has a laudable tradition of honoring promising projects every two years as part of Innovation Day. In 2022, projects in five different categories were highlighted.

Our employees have top qualifications in fields as diverse as acoustics, fuel cells, 3D printing and bionics. A total of around 1,000 engineers work at MTU, collaborating with six centers of competence and 16 universities to create new and innovative solutions for the future. Read more in the chapter → [Corporate social responsibility](#). We also achieve our excellent position by patenting our work; at the end of the year, MTU's patent portfolio contained 2,675 individual patents.

Research and development budget further increased

In the reporting year, MTU invested heavily in sustainable innovation: our investment in research and development (R&D) in 2022 totaled EUR 265 million (2021: EUR 230 million). With our R&D activities, we are actively promoting sustainable, zero-emission aviation while investing in MTU's future at the same time. R&D activities focused on performance improvements in the geared turbofan programs, technology studies for future generations of propulsion systems with an emphasis on hydrogen and flying fuel cells, and the expansion of capabilities in the area of virtual engines.

PIONEERING INVESTMENTS



265 m euros

We spent 15% more on research and development than in the previous year. These are investments in a green future. One area of focus is to make emissions-free flight a reality.

Strong research network

To sustain MTU's technological expertise, it is important to be adequately plugged into the research landscape. We maintain a network of some 100 universities, research institutions, and companies around the world. → [MTU's research network](#) MTU is involved in major research programs in Germany (LuFo aeronautics research program) and Europe (such as Clean Aviation) that push the development of ecologically efficient propulsion technologies for aviation. These programs bring together researchers from a wide range of manufacturers, universities and major research institutions.

RESEARCH PARTNERS



100

We have access to a strong network of universities, research institutions and companies and participate in important aviation research programs.

One cutting-edge technology program is the SWITCH project; launched in 2022, it combines MTU's Water-Enhanced Turbofan with hybrid-electric propulsion elements based on the geared turbofan. In addition, research into green technologies for aviation was further advanced as part of the Federal Aviation Research Program (LuFo) in Germany. Numerous project outlines and projects were approved for MTU concepts in 2022.

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