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European Association of the Machine Tool Industries
and related Manufacturing Technologies

THE INCREDIBLE LIFE OF A MACHINE TOOL

from birth to the beginning of a new cycle

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INTRODUCTION AND SCOPE

In recent years the environmental factor has gained more and more traction among the European Union's policymakers, leading to an unprecedented political momentum towards achieving a sustainable transition at the European level. This historic transition will require the overall industrial sector to play a very active role, to ensure that it can fully reap the economic and social benefits deriving from the realization of a truly sustainable society.

The EU is doing its part as well as on this matter, as it aims to energize the industrial transition through a policy mix of updated legislation and dedicated projects. In this regard, the European continent has everything to gain from the further development of sustainable applications and manufacturing technologies that optimize the utilization of resources and materials.

Nevertheless, embarking on a sustainable path entails fundamental shifts throughout the value chains, from product design, production processes and business models to consumption patterns, waste management and the use of secondary raw materials. This will in turn give rise to significant technological, financial, social and organizational innovations that will alter most of the existing dynamics within our sector.

Henceforth, through this document, we aim to demonstrate not only that the machine tool manufacturing sector can effectively lead the transition towards a circular economy, but that it is already rising to the challenge. Numerous industry players are rethinking traditional industrial processes, developing advanced manufacturing technologies, eliminating unnecessary waste and promoting the recycling and reuse of product materials. By embracing a whole life-cycle approach, the sector is starting to put the concept of circularity into action, and setting out a model for others to follow.

WHAT IS A MACHINE TOOL?

Machine Tool Technology

Machine tool technology is a critical and often unseen element of manufacturing since machine tools are at the starting point of almost every manufacturing activity. They are used to manufacture everyday objects such as home appliances, pens, bicycles, cars, planes, medical devices or wind turbines. The machine tool industry is a key enabling sector that has a direct impact on the productivity and competitiveness of European manufacturing, and thus in the transition to a circular economy as well.

According to ISO standard 14955-1:2017, a machine tool is a mechanical device, which is fixed and powered, typically used to process workpieces by selective removal or addition of material or mechanical deformation, through a process that can be mechanical, controlled by humans or by computers. Machine tools may have a number of peripherals used for machine tool cooling and heating, process conditioning, workpiece and tool handling (workpiece feeding excluded), recyclables and waste handling and other tasks related to their main activities.

They are thus extremely complex products that can be utilized exclusively for industrial uses. Bringing together hundreds or even thousands of components, including but not limited to nuts and bolts, bearings and pins, sheet metal enclosures and others, modern machine tools represent true engineering marvels.

Highly Heterogeneous Sector

One the key traits of the machine tool manufacturing sector is its heterogeneity in terms of company size as well as in the use and type of machine tool products.

There is an incredibly high variation in company size within the sector, which brings together small companies employing less than 10 people and manufacturing a few units per year, to large companies with thousands of employees that manufacture multiple hundreds of machines per year. Consequently, the company management and productive capabilities also differ greatly. The average European machine tool manufacturer is a Small or Medium-Sized Enterprise (SME), which collectively represent about 80% of our sector. The average number of employees per company, according to 2017 data, was around 106.

Aside from the company size, there is a significant variation in the types of metalworking machine tools produced, which makes them very diverse depending on their production processes. The most conventional production processes are cutting and forming: 1) Cutting machines (e.g. milling, grinding or boring machines) create a shape from a sheet or block of metal by using a tool with one or more cutting edges, whereas 2) Forming machines (e.g. stamping, bending or punching machines) create a shape by applying a force and using specially-shaped tools. In addition to these it is possible to find other "less conventional" production processes, such as laser cutting, waterjet cutting, electro-discharge machining, or a combination of different processes to obtain more complex components.

High Level of Customization

Taking into consideration the high variation in company size and production processes, and adding to this the high level of customization in terms of workpiece, materials, automation, speed and performance, it can be concluded that machine tools are indeed a highly heterogeneous group of products. In fact, there are rarely two identical machine tools on the market.

The machine tool manufacturing sector is a supplier of many European and international manufacturing industries, and product requirements are very different depending on their application. As a result, machine tools are rarely mass-produced, and in most cases, modifications to their basic design are needed to meet the customers' specific requirements in terms of workpiece geometry or production performance. Such high level of customization inevitably requires machine tool manufacturers to offer a wide range of services to the customer, including application engineering, maintenance, repair and on-site training of operators. For this reason, nowadays the manufacturers in our sector are increasingly providing contingent production solutions to their customers rather than only individual machines.

An Export-Oriented Sector

Notwithstanding the fact the vast majority of European machine tool manufacturers are SMEs, the machine tool market is highly export oriented. Currently, as of 2020, around 74% of CECIMO member countries' production is shipped abroad, whereas more than half – around 59% – is exported outside Europe, mainly towards China and the United States. Therefore, machine tools are produced for a global market and, in some cases, Europe is not the main source of sales. European producers are focused on high-end, customised machines with a relatively long production cycle, as opposed to standard machines with short lead times. The European machine tool industry is the leader on the global market, with a highly innovative, diversified and precise offer. Producers have kept their global market share at around 35% of the global machine tool market in recent years, but they are facing increasing competition from China, Japan or South Korea.

Circular Characteristics of Machine Tools

The current shift towards a circular economy will inevitably require a leading role from Europe's manufacturing sector. Considering that machine tools are at the starting point of most industrial value chains, and thus have a hand in most manufactured products, they have the ability to directly impact the productivity and competitiveness of almost every manufacturing process. For this reason, at CECIMO we believe that machine tools are a key enabling technology with a high potential to become the catalyst for a large-scale transition towards sustainable manufacturing.In particular, the product characteristics exhibited by machine tools which allow for extended lifetimes, optimal reuse, refurbishment, remanufacturing and recycling of products and materials, indicate that they would be an optimal candidate to enhance the scope for sustainable manufacturing in Europe, thereby contributing to Europe's transition towards a more circular economy.

Highly Recyclable Materials

Although machine tools are generally very diverse, around 83% of the machines are mainly made of cast iron, welded steel, and other metallic materials. These materials are easily recyclable and can be used to produce new products again and again with no loss of quality. In addition, metal components are economically valuable, and there is an incentive for metal to be recovered during the disposal of machine tools at the end of their lifetime – either by the manufacturer or by dedicated scrappers. According to the Ellen MacArthur Foundation, the overarching goal of circular economy is to retain as much value as possible for as long as possible in the economy, also in terms of product materials. Hence, the predominance of recyclable materials such as cast iron, steel and other metals in the composition of machine tools can greatly facilitate our sector's ability to replace virgin materials with recycled secondary raw materials, in a circular manner, on a European scale.

Lifetime of Machine Tools

The circular economy concept goes beyond the recycling of product materials. The key elements to consider here are the lifetime, reuse and remanufacturing of products, which allow them to retain as much value in the economy for as long as possible. In this regard, machine tools represent an ideal field for applying circular economy approaches since they are products with a long lifetime, which are highly prone to be repaired, reused and remanufactured. Data provided by our manufacturers shows that, on average, 80% of machines are still in service ten years after installation, while 65% are still in service after 20 years, thereby providing evidence of the durability and long lifetime of machine tools.

Furthermore, given their relatively high value, the repairing and remanufacturing of machines is very common in our sector, varying from small improvements to full rebuilds. According to data from the Ecodesign preparatory study on machine tools, 80% of machine tools are retrofitted and refurbished when they are between five and 15 years old depending on the specific sector and application. This is because machine tools are usually designed in a modular way. To reduce down-time of the machine in case of problems, access to key components for replacement is very much taken into account in the design of the machine. This simplifies maintenance, helps to reduce construction costs and facilitates remanufacturing and disassembly at the end of life. When a machine tool is remanufactured, it is often possible for newer more energy efficient components or controls to be added, thus leading to a reduction in the energy consumption of the whole machine.

Embracing Circularity

Based on the available evidence, it can be argued that machine tools are indeed sustainable products, and thus an optimal candidate to lead Europe's transition towards a circular economy. Machine tools possess great durability and a long lifetime, as shown by our industry data, which indicates that most machines are capable of remaining in service even after 20 years of continuous operation. They are largely composed of metallic materials (around 83%), which allow for high levels of recycling and reuse of materials, thereby giving rise to sustainable production cycles in an almost never-ending loop. Finally, machine tools are designed with a high ease of maintenance in mind, hence they are highly prone to be repaired, reused and remanufactured – retrofitting and remanufacturing have become standard practices in our sector.

Therefore, looking at their favourable characteristics, which allow for extended lifetimes, optimal reuse, refurbishment, remanufacturing and recycling of products and materials, it is clear that machine tools already embrace the key principles of the circular economy. Furthermore, given their critical position as the starting point of almost every manufacturing activity, machine tool manufacturers can have a direct impact on the productivity and competitiveness of European manufacturing as whole, and thus lead this transition towards a circular economy.

EXTENDING THE LIFETIME OF MACHINE TOOLS

Design

Machinery products often do not have a design that facilitates certain processes such as disassembly, cleaning, reprocessing or reassembly. Integrating remanufacturing and repairing in the design process can significantly increase product durability and allow for an easier execution of production tasks. As a matter of fact, machine tools are becoming increasingly modular in their designs, in order to reduce the downtime caused by an accident and to enable an easy and rapid access to key components whenever these need to be replaced or upgraded. To facilitate the adoption of this practice, it is essential to use or develop dedicated guidelines or standards that can ensure products' compliance with regulatory requirements, increase their remanufacturing and repairing rates, and ultimately lower the overall environmental impact of manufacturers.

In this regard, Additive Manufacturing (AM) represents an excellent tool for companies aiming to integrate remanufacturing and repairing in their design processes. AM has minimal shape and geometric constraints, thereby allowing the production of alternative optimized complex parts that have a lighter weight, enhanced durability and repairability, and improved functionality. This can reduce the consumption of energy and natural resources during the use phase, and thus minimize the manufacturers' impact on the environment.

In fact, AM is already being used in sectors such as aerospace, automotive and construction among many others, as new innovative improvements are constantly being developed. An example of such functional improvement can be seen in lightweight components for transport systems. AM-produced metal parts can be up to 50% lighter than machine parts. In areas such as aerospace or the automotive sector, the use of AM can translate into a positive effect on the environmental performance during its use phase. According to industry sources, one kilogram removed from every unit of a 600+ fleet of commercial jetliners can save about 90,000 litres of fuel every year, and reduce emissions by up to 230 tons of CO2.

Further benefits obtained through the use of AM can be found in the consolidation of the number of components within an assembly. A notable example on this matter is the CFM fuel nozzle tip, which combines 20 components into one, offering a five-fold increase in durability and a 25% reduction in weight. Fewer components to be assembled leads to simpler logistical requirements, lower need for tooling, fewer errors in production and a significant reduction in production and assembly time, resulting in costs savings and a lower environmental impact.

Additive technologies can also help reduce waste in the production process, since they only use the materials needed to produce a component. Although some form of post-processing of the component is often required, which generates waste in terms of support material and residual power, a large part of it can be recycled or reused. For metal powders, it is estimated that up to 95-98% can be recycled. In the case of plastics, waste plastic filament, misprints and undesired outputs can also be largely reclaimed and reused. In this regard, additive processes provide an opportunity for manufacturers to create additional value, by recovering waste as material to produce new components.

Therefore, the advent of additive processes in manufacturing will increasingly facilitate machine tool manufacturers to integrate remanufacturing and repairing in the design process, significantly raising product durability and allowing for an easier execution of production tasks. By reducing the consumption of energy and natural resources during the use phase, and lowering the level of waste in the production phase, the use of AM in the design process has a high potential to enhance sustainability and support the transition towards a more circular economy.

Maintenance

Reducing machine tool downtime and assuring product quality are important aspects to consider for the customers of machine tool manufacturers. However, both product quality and machine downtime heavily depend on the condition of the equipment. Digitalization and the permanent, remote monitoring of machinery condition makes it possible to reduce downtimes through the early detection of possible problems prior to the machine tool's failure. This is achieved by implementing predictive maintenance, which increases product reliability and availability, thereby enabling us to extend the lifetime of machinery products and ultimately lower their overall environmental impact.

Digital technologies, namely Artificial Intelligence (AI), Internet of Things (IoT) or Blockchain technologies, are a key element for the implementation of predictive maintenance, since they allow machines and production systems to connect, work together and to share, analyse and process data. These technologies use historical and real-time data from machine operations to anticipate problems before they occur, strictly based on the actual condition of the equipment, rather than on average or expected life statistics.

According to numerous studies, the use of predictive maintenance enables us to decrease total machine downtime by 30-50%, while increasing the machine's lifetime by 20-40%. Besides increasing the efficiency of maintenance operations, equipment data can also assist the repairing of machines. Having the data history of a machine means that manufacturers know the wear and tear of each component, and thus it becomes easier to identify the components that require intensive work or replacement and the ones that only require small adjustments or no repair at all.

This digitalization trend in maintenance operations, which is largely driven by advances in data, analytics and connectivity, provides numerous opportunities for the realization of sustainable and resource-efficient manufacturing. By extending machines' lifetime, reducing their downtime and use of resources, predictive maintenance allows companies to optimize manufacturing operations, maximize energy efficiency and thus reduce their overall environmental footprint. For this reason, the widespread use of digital technologies for predictive maintenance can play a fundamental role in bringing a change towards a more circular manufacturing sector.

Retrofitting

After ten or more years of operation, the mechanical components of machine tools are usually still in good condition. However, control and drive technologies always continue to advance steadily, introducing new functions that make production more economical, more energy-efficient, and thus more sustainable in the long-term. Retrofitting is a process that improves the machine tool's original specifications via procedures like replacing components, modules or adding novel technologies that extend its lifetime. Since retrofitting is able to restore or even enhance the required reliability of a machine at a lower cost than purchasing a new one, it has been identified as an effective measure to boost productivity and reduce waste levels, and ultimately extend the lifetime of a machine tool.

Digital technologies play an important role in retrofitting processes, particularly with the use of smart enablers with physical and digital components that can add capabilities to machine tools. Machine tools' lifetimes can be extended through the use of various digital technologies, including but not limited to Artificial Intelligence (AI), Internet of Things (IoT) or Blockchain technologies. These can improve transparency, performance monitoring, data-driven operations, and in turn increase the lifecycle of a machine tool. In fact, retrofitting allows manufacturers to fully reap the benefits of technological advancements into the existing machine concept and to render it a state-of-the-art machine, without having to purchase a brand-new one, thereby significantly reducing the environmental impact of their manufacturing activities. Thus, retrofits are a highly effective way to give older machines access to new innovations by replacing old functions with new ones, while enhancing the scope for circular manufacturing in our sector.

The most common type of retrofitting in the machine tool manufacturing sector is the CNC (Computer Numerical Control) retrofit – the process of replacing the CNC, serve and spindle systems on an otherwise mechanically sound machine to extend its lifetime. The foreseen benefits of CNC retrofitting include a lower cost investment than purchasing a new machine and a marked improvement in machine uptime and availability, however, there are further benefits to it including lower energy consumption, higher performance and a new level of manufacturing data accessibility. Especially in terms of energy savings, when combined with the more efficient machining processes provided by the CNC, machine electricity consumption can be reduced by as much as 30% to 50%, thereby lowering the overall environmental impact of machine tool manufacturers. As a result, retrofitting processes, through the use of digital technologies, can significantly improve the environmental performance of machine tools and their level of circularity by extending their lifetimes far beyond their baseline potential.

RECYCLING MACHINE TOOLS

Remanufacturing

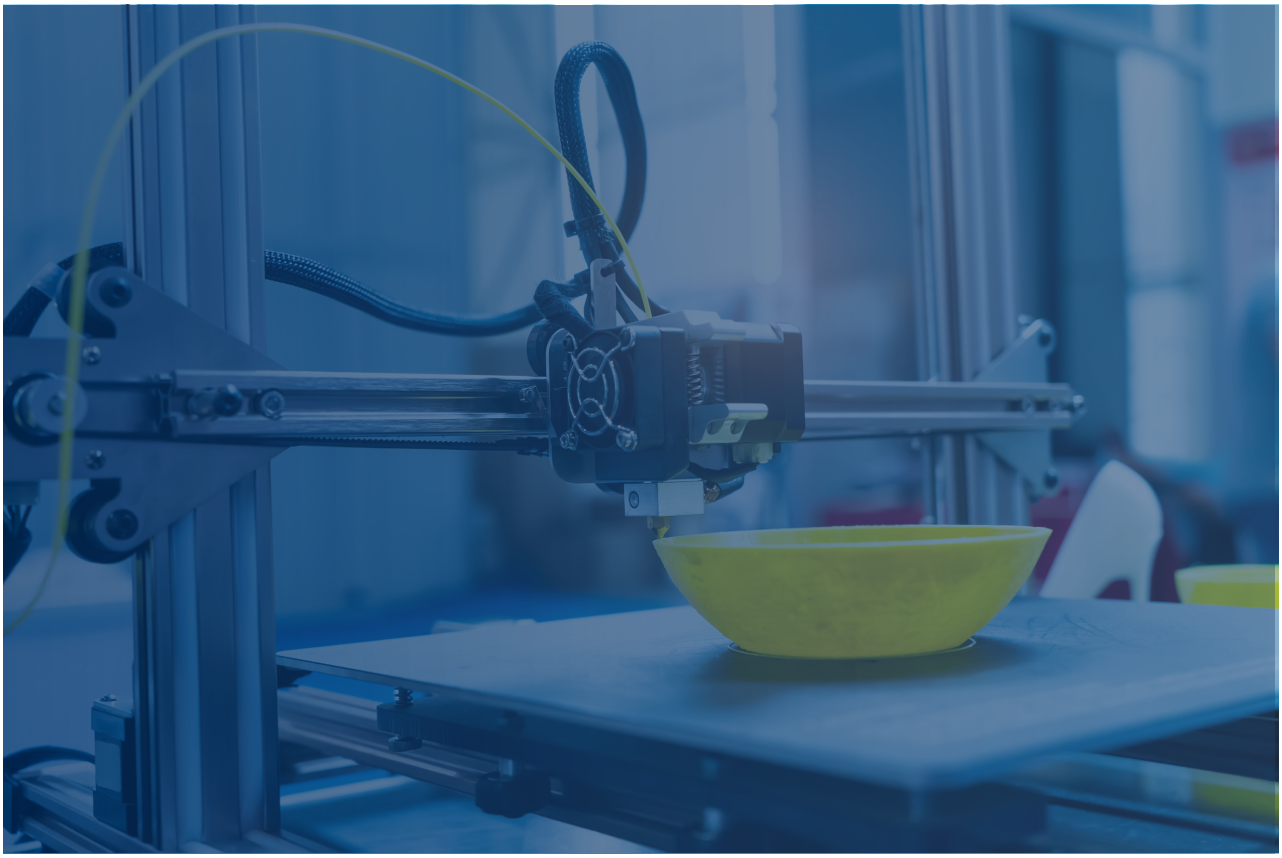
Remanufacturing is "the rebuilding of a product to specifications of the original manufactured product using a combination of reused, repaired and new parts," following the repair or replacement of worn-out or obsolete components and modules. This process is fundamentally different from other product recovery processes, in terms of its completeness, because a remanufactured machine is expected to match the same customer expectations as new machines. In fact, remanufactured products are often of higher quality because once returned they are fully stripped down, allowing full diagnosis of failure modes. Besides offering sizeable advantages in terms of product quality, production costs and downtimes, remanufacturing also brings considerable environmental benefits that can increase the scope for sustainable manufacturing.

In our view, the widespread adoption of remanufacturing processes by manufacturers is a fundamental requisite to achieve a well-functioning circular economy at the European level, especially owing to its numerous environmental benefits outlined below. First of all, remanufacturing preserves much of the material contained in the original product, and thus fewer raw materials are used than would be for manufacturing new products. This is particularly important when it comes to critical raw materials, which are highly prone to supply chain risks. Secondly, by limiting the quantities of raw materials extracted/recycled and the manufacturing of new components, remanufacturing typically consumers less energy than manufacturing new products from scratch.

Thirdly, and consequently, the reduction in energy consumption achieved through remanufacturing is usually accompanied by an overall reduction in CO2 emissions. By keeping components and their embodied material in use for longer, significant energy use and CO2 emissions to air and water can be reduced. Henceforth, the large-scale adoption of this product recovery process is an essential step for the achievement of a resource-efficient manufacturing industry, and ultimately to lead the transition towards circular manufacturing.

Additive Manufacturing (AM) can play a crucial role in supporting our sector's transition towards a circular economy, by making remanufacturing and repairing easier and more cost-effective. Often times, parts needed for repair may not be available, may take too long to be delivered or may not be cost-effective. AM allows spare parts to be printed on demand and closer to where they are needed, thereby reducing inventory waste and customer waiting time. Deutsche Bahn, the German railway company, is a notable case of a company using AM to produce spare parts that are no longer in circulation or extremely difficult to retrieve, particularly for the older vehicles and infrastructure systems. In these cases, additive technologies offer a more effective alternative to the traditional production of small quantities, with a far lower environmental impact, especially from the perspective of resource utilization.

The repair of damaged components allows machines to last longer and avoids the production of new ones, offering considerable environmental benefits in addition to the economic ones. According to a comparative Life Cycle Assessment (LCA) conducted on turbine blades, the reparation of a damaged turbine blade by AM, compared to producing a new one by casting, can achieve energy and carbon footprint savings of 36% and 45% respectively. Henceforth, rather than replacing damaged components altogether, additive technologies can be used to repair or remanufacture the damaged areas, resulting in simplified repair, decreased downtime, extended lifetime, all of which collectively work to reduce the overall environmental impact of manufacturing. In this regard, the use of additive technologies for the remanufacturing and repair of damaged machines can be a strong catalyst for our sector to lead the circular economy transition at the European level.



CECIMO RECOMMENDATIONS FOR POLICYMAKERS

The transition towards a circular economy will require fundamental changes throughout different value chains, impacting product design, material use, production processes, business models and waste management dynamics. With an adequate approach, this transition could boost technological, financial, social and organizational innovations, as well as establish a more sustainable industrial ecosystem in Europe. In this regard, CECIMO would like to advance the following recommendations for policymakers to facilitate the spread of sustainable manufacturing:

1 Avoid a one-size-fits-all approach

The machine tool manufacturing sector encompasses a wide range of machinery products and companies (SMEs for the most part), and thus the requirements need to be set on a product group-specific basis, which is easily measurable, evidence-based and harmonized at the EU level. Policy and legal initiatives should actively involve the manufacturing sector and properly balance environmental sustainability principles with economic sustainability, to avoid any additional burdens that could lead to a loss of competitiveness of European companies.

2 Support the digitalization of European industry, with a strong focus on SMEs

The use of digital technologies in manufacturing can enhance energy and resource efficiency, and contribute to keeping materials in use for a longer time. To promote digital solutions, it is important to exploit synergies between different EU initiatives in the field of circular economy (Sustainable Product Policy, "Less Waste, More Value," etc.) and to provide financial incentives that can support the digital transformation of manufacturing SMEs.

3 Access to R&D funding for manufacturers and promote development of advanced manufacturing technologies

Achieving sustainable manufacturing will require a transitional period in which R&D incentives support and promote the development of new technologies to shift towards different production processes and value chains. The adoption of advanced manufacturing technologies, including but not limited to Additive Manufacturing (AM), Artificial Intelligence (AI) or machine learning, can enable the transition to a more circular economy.

4 Financial and policy incentives promote sustainable production practices

Sustainable practices such as repairing, retrofitting or remanufacturing are fundamental to improve product performance and to ensure better monitoring, transparency and data analysis. To promote these new technologies there must be clear incentives frameworks that can guide and facilitate the manufacturers in their transition (Improved access to finance, increased standardization for sustainability, etc.).

CONCLUSION

Based on the evidence presented in this document, it can be argued that machine tools already embrace some key principles of the circular economy, especially in terms of production, products and materials. Machine tools are designed to allow for extended lifetimes, optimal reuse, refurbishment, remanufacturing and recycling of products and materials, and retain a high margin for performance improvement. As previously stated, these characteristics indeed make machine tools an optimal candidate to enhance the scope for sustainable manufacturing in Europe, and thus contribute to Europe's transition towards a more circular economy.

But perhaps most importantly, this document clearly shows that besides displaying favourable characteristics for circular economy approaches, the machine tool manufacturing sector is already rising to the challenges entailed by Europe's sustainable transition. Numerous actors are rethinking traditional industrial processes, eliminating unnecessary waste, developing innovative advanced manufacturing technologies – particularly Additive Manufacturing (AM) and digital technologies – and doing all they can to promote recycling and reuse. In fact, machine tool manufacturers are increasingly looking for ways to improve the performance of their machinery products, through design, maintenance, retrofitting or remanufacturing, thereby improving their products' performance from an environmental standpoint. By embracing a whole life-cycle approach, the sector is starting to put the concept of circularity into action, and setting out a model for others to follow.

In this regard, it is important to highlight that machine tools and related manufacturing technologies can have an enormous impact in terms of supporting sustainable manufacturing processes. The sector provides numerous process and product innovations, allowing for better control of the manufacturing process and traceability, which results in extended lifetimes, less waste, more efficiency and better management of resources. Putting stronger emphasis on resource and energy efficiency does not represent a shift away from traditional elements of competitiveness such as precision, speed or reliability and safety. It rather adds to these strengths the element of sustainability, which emerges as a new paradigm of competitiveness. Environmentally efficient machine tools can hugely profit both machine tool manufacturers and users – the users can save on material and energy costs thanks to optimised production processes, whilst the manufacturers can gain a competitive edge by offering value added products.

Given their critical position as the starting point of almost every manufacturing activity, machine tools are a key enabling technology that can have a direct impact on the productivity and competitiveness of European manufacturing as whole. Thanks to more accurate, efficient and capable machine tools the European manufacturing industry can improve its productivity and resource efficiency and consumers can enjoy manufactured products that last longer and use less energy than ever before. As the shift towards a circular economy calls for a prominent role of the manufacturing sector, the machine tool manufacturing sector can, in our view, effectively lead and support this transition.

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CECIMO is the European Association of the Machine Tool Industries and related Manufacturing Technologies. We bring together 15 national associations of machine tool builders, which represent approximately 1500 industrial enterprises in Europe (EU + UK+ EFTA + Turkey), over 80% of which are SMEs. CECIMO covers 98% of the total machine tool production in Europe and about 34% worldwide. It accounts for approximately 150,000 employees and a turnover of around 20 billion euros in 2020. More than three quarters of CECIMO production is shipped abroad, whereas half of it is exported outside Europe.