We Transform Business

Helping our clients and suppliers transform to operate within planetary boundaries

The metals and mining industries must evolve to significantly reduce their carbon emissions in order to limit global warming to internationally-agreed limits. Tenova is helping drive this transformation by developing innovative technologies that not only help our clients deliver better products but also drastically reduce their environmental impact. In our efforts to transform our industries, we are also transforming our own business by seeking opportunities to reduce our environmental impact and operate more efficiently.

In this section, we report on how we help our clients reduce their own environmental impact through our varied portfolio of products, technologies, and services, with a focus on digital transformation. Lastly, we report on our own energy consumption and related emissions.

1. Driving Value for Our Clients

Our portfolio of solutions is principally dedicated to the sustainable transformation of the metal and mining industries. We create value for our clients by providing innovative technologies that ensure efficiency, resulting in better performance, less waste, and lower carbon emissions. We provide technologies that support the transition to cleaner fuels, utilize energy more efficiently, and recover and reuse previously wasted material. In developing these solutions, we are not only serving our clients, but are also working hard to accelerate our sector's transition to a lower environmental impact.

1.1. Energy Transition

The iron and steel industry is one of the largest emitters in terms of global direct energy-related CO_2 emissions[1]. The steelmaking industry is moving towards **natural gas-based and hydrogen-based iron reduction as substitutes for carbon-based processes**. However, current raw material supply chain shortages and the geopolitical tensions affecting natural gas availability make this transition challenging.

Tenova is fostering a **shift in the energy paradigm** in the metals industry by promoting the use of **hydrogen-ready technologies** to its clients for the transformation process of their business. This is also carried out by means of partnerships and collaborations with gas supply operators, electrolyzer manufacturers, and other third parties that support a green energy transition.

Tenova also contributes to the energy transition by **promoting the use of electric and hybrid vehicles**, in order to reduce emissions, improve air quality and a healthier environment for our communities and employees.

1 International Energy Agency (IEA), "**Iron and Steel Technology Roadmap: Towards more sustainable steelmaking**" (2020).

Electrical Steel

As the world invests in electrical vehicles and improves the electrical grid infrastructure, the appetite for **electrical steel grades** is growing substantially. Electrical steel is required for transformers, for the expansion of the electricity infrastructure and for rotating machines such as wind turbines and electrical motors. Tenova has developed **numerous technological advancements to make electrical steel even more efficient**, including several technological developments in the annealing, pickling, decarburization, flattening, and coating operations required in strip processing.

Indirectly, Tenova's technologies influence downstream technologies as well, enabling our customers to more efficiently produce metals that are critical to facilitating the energy transition. One example is **electrical steel**, or **silicon steel**, which makes up roughly 1-2% of total crude steel production globally. Electrical steel is an **iron-carbon alloy with silicon** as its primary additive. It is highly valued for its ability to conduct magnetic fields, minimizing power losses.

CASE STUDY

Improvements in Silicon Steel

As the demand for silicon and magnetic steel increases due to growing demand for electric vehicles, Tenova's R&D team has been hard at work to develop technologies to improve the silicon steel-making process. In addition to our suite of technologies for silicon steel, we have been working on improving the magnetic properties of silicon steel through hot band cold rolling and new descaling processes, like laser and other mechanical descaling. Our research intends to find the optimal process to improve surface finishing and enhance magnetic properties.

DRI and ENERGIRON

The partial or total use of hydrogen for **DRI (Direct Reduced Iron)** production is an excellent source of carbon reduction. This solution is already widely adopted in the industry and has become the standard for the **decarbonization of integrated steelmaking** (i.e., steelmaking from ores as raw materials).

ENERGIRON is an innovative HYL Direct Reduction technology, jointly developed by Tenova and Danieli. It has been designed to use **different types of reducing gas sources or pure dihydrogen** to reduce iron ores into metallic iron used in melting facilities to produce a wide range of **high-quality steels**. ENERGIRON plants efficiently reduce any iron pellet or lump into "energized" hot or cold DRI or hot briquetted iron with controlled metallization and carbon levels. ENERGIRON offers unparalleled flexibility: even with the same process scheme configuration, the client can select the best energy source — natural gas, reformed gas, syngas from a coal gasifier or even coke oven gas — without any modification and control the amount of embodied carbon. ENERGIRON plants meet the **most stringent environmental regulations** as well. Because of its unique features, it has the lowest carbon footprint of any ironmaking technology, with the further advantage that selectively removed CO_2 can be sold. Additionally, the water byproduct of the reduction reaction, easily condensed and removed from the gas stream, can be used as cooling water in a zero-water consumption circuit.

DRI plants are typically coupled with **electric arc furnaces (EAF)** for the melting of DRI and its transformation into sellable iron or steel, in which the use of electrical energy substitutes chemical energy (which creates CO_2 emissions). The world's most productive DRI-fed EAF in the world was produced by Tenova and we are currently embarking on building a second one.

SAF and Open Slag Bath Furnace

Open Slag Bath Furnace (OSBF) is the perfect solution for melting high carbon DRI to produce hot metal. The electric furnace — a **Submerged Arc Furnace (SAF)** in this case — works using Søderberg electrodes operating with a very short electrical arc or "brush arc". It can tap hot metal into torpedo cars. The resulting slag has the same composition as blast furnace slag. The slag produced is similar to blast furnace slag and can be sold to the cement industry. The work done on OSBF slag treatment has identified a potential alternative processing route for the treatment of black slag, discussed in more detail below.

Mineral wool applications

Historically, the mineral wool flow sheet has included Cupola furnace technology, a process with high carbon emissions. Tenova has identified the use of a bespoke hybrid SAF design (using graphite electrodes) to replace Cupola furnaces. This technology change has the potential to reduce mineral wool carbon emissions by up to 90% depending on the electrical energy carbon footprint. Tenova offers this technology to existing mineral wool producers (as a retrofit) or producers planning to expand their mineral wool production capacity.

iBLUE®

The emissions from the conventional blast furnace-basic oxygen furnace or oxygen converter (BF-BOF) route represent the greatest potential for CO_2 reduction in the steelmaking industry: the BF-BOF route from iron ores produces two tons of CO_2 for each ton of steel produced (while the EAF route from scrap produces 80% fewer emissions). As of 2019, 71% of global steel was produced via the BF-BOF route, while only 29% was produced via the electric (EAF) process. Tenova's proven technology to **substitute any Blast Furnace** is iBLUE® which enables the **production of Liquid Pig Iron via the BF-BOF route** while massively reducing emissions. iBLUE® combines the production of high carbon DRI with an electric arc melter to produce hot metal and granulated slag. iBLUE® can also utilize BF grade pellets as raw material, making this solution the perfect substitute to blast furnace technology. The use of green hydrogen in the reduction process can further **minimize greenhouse gas emissions**. This represents a less costly option to produce pig iron with a negligible carbon footprint and results in minimal disruption to the operations of an integrated steel plant that plans to shift towards green steel production.

In 2023 Tenova started a test campaign on an industrial size submerged arc furnace for the production of hot metal with positive results. Increasingly, iBLUE® is establishing itself as the sustainable alternative to Blast furnaces to convert integrated steel mills with existing BOFs into "green metal plants". In addition to the environmental advantages, iBLUE® allows steelmakers to maintain existing steel grades production procedures and quality control: from this perspective, implementing iBLUE® does not require the qualification of the production process and it is highly recommended for high quality steel grades, exposed automotive parts etc.

A number of projects and studies have started in 2023 with steelmakers in different parts of the world that may lead to the construction of new iBLUE® plants in the near future.

Combustion Systems for Furnaces

Traditional hot rolling heat treatment and melting processes utilize fossil feedstocks resulting in a high carbon footprint for final products like long or flat products. Tenova is committed to developing and deploying **clean-burning hydrogen-based solutions** for reheating and heat treatment furnaces. Since 2008, we have specialized in the development of **regenerative and self-regenerative burners** that provide at least a **10% reduction in CO_2 emissions** using fossil feedstock. However, Tenova's regenerative burners are **hydrogen-ready**: whenever green hydrogen becomes readily available, our clients can immediately swap to the clean-burning fuel and drastically reduce their carbon emissions without any additional adaptations to their equipment.

We have also integrated this latest technology into our line of **SmartBurners** to provide up-to-the-minute data on the operating efficiency and processes of our burners to ease inspections and maintenance. Our **Industrial Internet of Things (IIoT)** framework offers a complete set of process diagnostics, KPIs to control key parameters like the combustion ratio, leakage of switching valves, and combustion quality. Our multi-megawatt TSX SmartBurner family for reheating and non-ferrous melting furnaces is fueled with a mixture of natural gas and hydrogen – it can run on 100% hydrogen as well. Our 200-kilowatt TRKSX (Tenova Self-ReKuperative Flameless) SmartBurner also uses a variable fuel mixture of natural gas and hydrogen and works in flame and flameless mode, helping to keep **nitrogen dioxide emissions well below the strictest limits.**

In 2021, we reached a key milestone in this endeavor by developing the first burners for heat treatment furnaces using up to **100% hydrogen**, while keeping NOx emissions below even the strictest limits. Tenova's regenerative flameless burners combine the lowest NOx emission levels with high temperature combustion air preheating, while allowing a drastic reduction of CO_2 emissions through high combustion efficiency. That means our products provide clients with improved plant sustainability even before cleaner fuels become available.

In a collaboration project with one of our customers, Tenova LOI Thermprocess proceeded with advanced heating hoods, featuring the patented **Ultra low NOx HPH®-flameless concept** and increased air preheating temperatures to 600°C, achieved up to 12% energy and CO_2 savings. In production trials, the project aimed at decarbonizing steel production by gradually shifting the fuel gas supply for the heat treatment of hot-rolled narrow strips **from natural gas to 100% hydrogen**. Despite the higher combustion temperature, the flameless concept resulted in low NOx emissions.

To assess the impact of increased hydrogen use on the overall system, a mobile natural gas/hydrogen mixing station was employed. This allowed us to test different gas mixtures during annealing cycles. To this end, Tenova developed the THSQ Burner family that is capable of working with any hydrogen/natural gas mixture by keeping consistent thermal performance and Nox emissions. The tests consistently confirmed that Tenova LOI Thermprocess' Ultra low NOx HPH®-flameless bell-type annealing plant is well-suited for hydrogen use.

TenovaLAB

We continuously invest in new research and development activities to create cutting-edge technologies that provide low-carbon solutions to our clients in the metals and mining industries. For this reason, Tenova has invested in its own R&D facilities by installing an **experimental laboratory in our headquarters in Castellanza**. Our TenovaLAB carries out experimental industrial activities for the development and testing of all burner technologies. Equipped with **four test furnaces** of different thermal power, TenovaLAB allows our R&D team to close the loop between our in-house modeling and simulation capabilities and the engineering of industrial products. On-site product testing, like thermal and emissions measurement, enables us to fine-tune product specifications, minimizing technology risks for our clients. Furthermore, TenovaLAB allows our customers to see our products in use in real operating conditions.

During 2023, we continued to expand our facilities at TenovaLAB with preparatory works for the installation of a 1.5 MW **water electrolysis unit** directly connected to the solar panels roofing of our Pomini factory. This expansion is partially financed with a HorizonEU grant to demonstrate the green hydrogen production/utilization chain at full industrial scale, from electrolyzer generation of hydrogen to the blending with natural gas in the furnace combustion system.

CASE STUDY

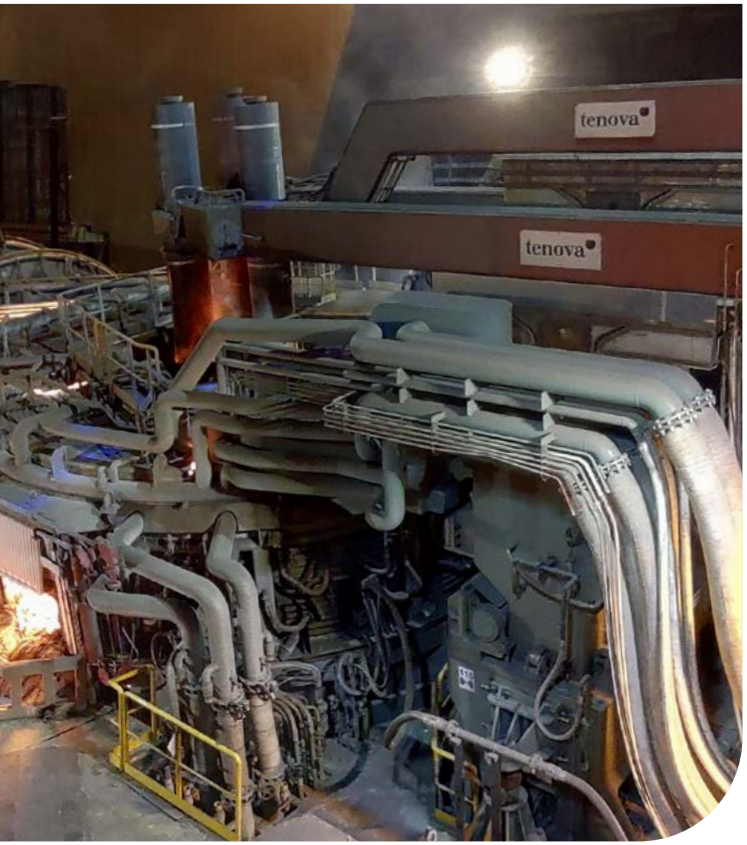
Partnering with Clients for a Low-Carbon Future

As our economies move towards net-zero emissions, steel companies have a major role to play in emissions reduction. Tenova is constantly innovating to develop low-carbon solutions for the metals industry:

- We partnered with Snam, Europe's largest energy infrastructure operator, to conduct joint strategic studies and market analyses to implement green hydrogen projects in the metals industry. The aim is to bring integrated, turnkey commercial solutions tested in industrial plants to implement a substantial reduction of CO_2 and NOx emissions in metals production processes – from melting up to thermal processing of long and flat products.
- We have partnered with Tenaris and Snam to pilot green hydrogen steelmaking at Tenaris Dalmine's pipe mill on our "Dalmine Zero Emissions" project. The project marks the first industrial-scale application of hydrogen in Italy to decarbonize the steel sector. The project aims to generate hydrogen and oxygen by installing a 20 MW electrolyzer and will likely include the construction of a storage site for the accumulation of high-pressure hydrogen and the use of oxygen in the melting process. The results of the project could significantly reduce CO_2 emissions related to electric arc furnace steelmaking.

1.2. Energy Efficiency

In cases where it is not yet feasible to transition to cleaner fuels, we have developed a suite of technologies to help our clients use their existing fuels more efficiently or adapt their existing processes, thus reducing their emissions. One such example is our Ferrochrome Multiple Preheater technology which reduces electrical energy consumption by preheating the ores before they enter the furnace using the furnace waste gases, recovering the energy otherwise lost to the environment.



Consteel® & EMS

In use for over 30 years and in 80 sites across all continents, our **Consteel® Electric Arc Furnace (EAF)** has proven its value to clients around the world. Consteel® is a process by which raw feed materials, in particular scrap, are preheated and charged continuously into an EAF and melted by immersion in the liquid steel present in the furnace. The EAF operates in constant flat bath conditions, a key advantage over conventional batch processes where scrap is melted by the direct action of the electric arc. **EAF gases are used to preheat the incoming scrap and feed materials**. Their composition is controlled and sent to a fume-cleaning plant in conditions suitable for the complete combustion of carbon monoxide and other pollutants without any fuel consumption. This process produces liquid steel with high productivity, a short and adjustable heat cycle, and the lowest power cost compared to any other EAF installation using conventional or other alternative steelmaking technology.

Although 30 years have passed, the technology is still considered modern. Recently Tenova introduced additional features, like the **Electro Magnetic Stirring (EMS)** technology, to improve energy consumption and refractory lining life.

CASE STUDY

Multiple Pre-heater, for FeCr production

In 2023 Tenova, together with one of the worlds largest Ferrochrome producers, successfully commissioned and tested Tenova's patented multiple pre-heating system. The system utilized the chemical energy contained in the furnace off-gas as a fuel to pre-heat the chromite feed materials. This technology reduces the electrical energy requirement (directly decreasing the operating cost per ton product) and it has the added advantage of improving furnace stability.

iRecovery® Captures and Reuses Thermal Heat

Today, process optimization and energy efficiency to reduce emissions are more important than ever for steel producers. Tenova began working on this over a decade ago, well before other companies were thinking about sustainability in the industry. We developed the **iRecovery®** system for recovering thermal power from EAF waste flue gas and using it as an energy source. This energy comprises the biggest fraction of the primary energy input in the EAF process yet typically goes to waste. iRecovery® captures the thermal energy created by the off-gas and uses it to produce steam to power steelmaking and other activities. In Brescia, for example, our client ORI-Martin uses iRecovery® at their steel plant. The captured heat from their plant heats 2,000 homes in wintertime and powers 700 homes in the summer, reducing 10,000 tons of CO_2 every year. In 2023, Tenova developed iRecovery solution for application at high pressure, till 60bar(g). The solution increases the applicability of iRecovery in the transformation process of steelmaking from BF-BOF to DRI-EAF through integration into the existing steam network.

1.3. Circular Economy

Industrial processes create numerous byproducts. Our solutions contribute to the circular economy by enhancing their recovery and reuse through our technologies.

Auto catalyst and battery recycling

Melting furnace technology is used to recycle the PGM's (Precious Group Metals) contained in spent auto catalysts. As the first generation of electric cars reaches the end of its cycle, there is a **real opportunity to recover valuable materials contained in various electric car systems** (mainly the battery and auto catalyst). Tenova offers both **hydro and pyrometallurgy process paths to recover these materials.**

Extracting value from black slag

Black slag is a by-product of the EAF steelmaking process. Due to the oxidizing operating mode of the EAF, the slag contains up to 30% FeO. An Open Slag Bath Furnace (OSBF) is the perfect solution for processing the black slag, and due to the reducing environment of the OSBF, the slag may be modified to produce pig iron and a white slag that is suitable for sale to the cement industry. The technology is complementary to the DRP-EAF processing route and is not a substitution for the primary steelmaking process. This initiative is developed in conjunction with the work done on slag valorization initiative.

EAF-LF (Electric Arc Furnaces - Ladle Furnace)

The primary production of steel from virgin iron ore is highly energy intensive. This can be mitigated without loss in quality by using ferrous scrap mixed with DRI/HBI and other virgin iron units (pig iron / hot metal) when necessary. Quality and availability of steel scrap are therefore an important factor, especially considering the trend in the quality of world steel scrap shows a decrease in quality. Having this in mind, we are conducting research and implementing the **new Industry 5.0 technologies** to manage low-quality scrap in furnaces and improve EAF flexibility and economic impact in favor of better sustainability. EAF steel production is already an integral part of the circular economy.

Tenova is implementing innovative approaches to increase the recycling process, replacing the use of injected coal in the EAF with alternative materials that are byproducts from other industrial processes, like polymers from waste plastic and by treating EAF process residues, such as slag and fume dust to recover both metal and mineral fraction for internal use or application in other industries.

Dry Slag Granulation

Tenova has developed a **ladle furnace slag granulation solution**, which uses forced air steam flow to rapidly cool and solidify slag. The fast cooling transforms the slag from liquid to solid which enables the possibility to re-use the slag as raw material in construction industry. Our solution decreases workers' exposure to harmful chemicals in slag, reducing water use, and reducing the need for virgin lime. Further, Tenova extended its dry-granulation technology to EAF slag obtained by high alloy steel production process and slag produced by the DRI/EAF process.

In 2023 Tenova was awarded with the first contract for the installation of the LF dry slag granulation solution system in Italy, which will process more than 20.000ton/year of slag. This plant is a first of a kind, it will be equipped with the most modern artificial intelligence algorithms to assist production optimizing the granulation process. The granulated product will then be utilized for the preparation of chemicals for the construction industry.

Lithium Recovery

Lithium is widely used in metallurgical processes to promote metal melting, eliminate the formation of oxides, and absorb impurities. Its growing use **in clean energy technologies**, like solar arrays and electric vehicle batteries, make it a crucial metal for achieving a net-zero future. Building on this potential, Tenova engineers have explored various processes to produce lithium more efficiently. **Tenova Advanced Technologies (TAT)** adapted its SX technology for producing **lithium from primary sources** to produce recycled **lithium from batteries**. The new process can be applied across all feed streams, originating from any source, including solar, hard rock, recycled waste, and process waste streams, to produce high quality lithium hydroxide. The key characteristics of this process are the **high efficiency of extraction**, superior to the traditional process, and a **lower use of water**.

1 *European Steel in Figures*, Eurofer, 2019, eurofer.eu

Twin-chamber furnaces for aluminum

Aluminum's many useful qualities have made it ubiquitous across all areas of modern life. Additionally, its recyclability makes it a highly valuable material. **Recycling aluminum uses only 5% of the energy it takes to mine virgin material** and creates fewer emissions. Tenova has created new technologies to further enhance the environmental benefits of recycling aluminum. Our **Twin-Chamber Melting Furnace (TCF®)**, a **Tenova LOI Thermprocess** technology, enables the remelting of organically contaminated aluminum or other scrap metal without pre-treatment. Its dual chamber design includes a post-combustion process to completely incinerate contaminants and use the resulting energy generated for furnace processes, thus reducing consumption of external energy. Our TCF® technology has **30 installations worldwide**, producing approximately a combined 1,500,000 MT of liquid aluminum every year. And for existing casthouses, the application of TCF® to the recycling of post-consumer scrap can significantly reduce the overall CO_2 emissions of the plant, as the process generates only 80 kg of additional CO_2 per ton of liquid aluminum.

Magnesia Metal from Coal Ash

As global demand for magnesium metal rises, Latrobe Magnesium Limited (LMG) in Australia is using Tenova's technology to harvest magnesium metal from fly ash byproduct – a hazardous waste material deriving from brown coal power generation. Originally developed to have a zero-waste pickling process during steelmaking, our pyro hydrolysis process was adapted to LMG's unique situation to recover magnesium metal. The related emissions from this technology are roughly half of those of conventional magnesium production plants. Launched in 2022, LMG is currently building its 1,000 tones per annum magnesium demonstration plant in the Latrobe Valley of Victoria integrating the Tenova Spray roaster unit. From the production experience acquired through this initiative, LMG eventually intends to develop a commercial scale operation producing 10,000 to 40,000 tons of magnesium metal per year.

1.4. Impact Monitoring

As a responsible company in the metallurgy field, we recognize the importance of monitoring the impact of our products and services on the environment and human health. We are committed to improving our processes and products to ensure their impact is accounted for along their entire life cycle.

Pomini Digital Texturing™

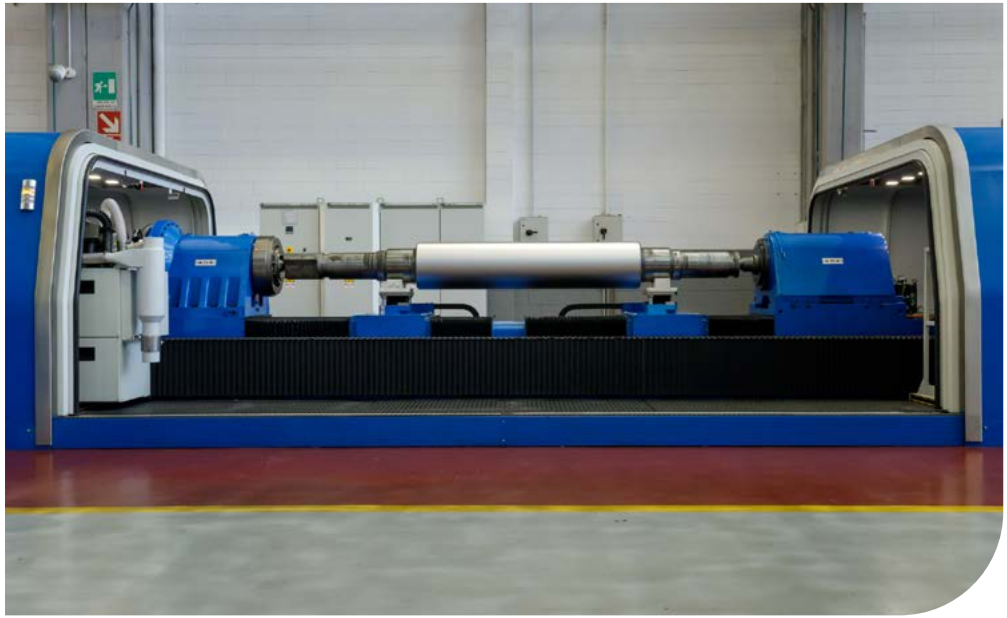
Our **PDT™ Pomini Digital Texturing™ process** covers an extensive range of **surfaces for work roll texturing** in cold rolling mill applications for both the **steel and aluminum** sectors. With up to four state-of-the-art lasers and no need for ancillary equipment, the process requires **minimal power consumption**. A simple digital process, based on modern **fiber-optic laser heads**, PDT™ enables an unparalleled range of surface possibilities compared to any other existing texturing technology.

PDT™ offers **benefits beyond energy efficiency**. It does not have adverse impacts on human health. Other texturing technologies may require, as a post-process in many applications, the use of significant quantities of hexavalent chromium, a highly carcinogenic material which can be difficult to remove from the environment. PDT™ makes it possible to significantly reduce, and even completely **eliminate hexavalent chromium**, making it a much safer and less toxic alternative.

Looking ahead, Pomini Tenova foresees **several exciting potential uses** for the revolutionary PDT™ technology. One potential use we are currently exploring is in the field of electrolyzers, designing a machine that converts water into hydrogen to be used as a clean-burning fuel – a key enabler of a low-carbon future. A second area of development is in electric vehicle batteries. We are exploring the use of PDT™ on aluminum foil to obtain a reduction in intrinsic resistance characteristics through texturing. We look forward to sharing more about these and other potential applications in the future.

PDTTM becomes "Product Category Rule" through Life-Cycle-Assessment (LCA) as per ISO 14025:2006

In 2021, Pomini Digital Texturing™ (PDT™) became the first machine in the metal surface finishing sector to complete a lifecycle analysis (LCA). As a result, the technology was certified as complying with the ISO 14025:2006 standard. The LCA analysis was registered on the EPD® Portal – the platform of the International EPD® System, the world's leading global LCA program operating in accordance with the ISO 14025, ISO/TS 14027, and ISO 14040, among others, standards – and is **now accessible to all users**. Subsequently, thanks to the experience gained through the LCA process, Pomini Tenova led the creation of the "Product Category Rule" – the rules, requirements, and guidelines to develop a high-quality EPD for a specific product category, ensuring that functionally similar products are assessed and compared in the same way when measured through an LCA.



1.5. R&D and Sustainable Innovation

We not only improve existing technologies for metals industries, but also design and produce new technologies that reduce the environmental impact of our clients' facilities while improving production efficiency and performance. Our solutions reduce CO_2 emissions to some of the lowest levels in the metals industry. We create cutting-edge technologies that **reduce fine particles**, NOx emissions, dioxins, and other hazardous substances. We strongly believe in the potential of alternative and renewable energy sources, incorporating them into our solutions wherever possible. We have already put **hydrogen-ready technologies** on the market, and many of our solutions are designed around the concept of **recovery, reuse, and circularity**, from dispersed energy to reutilized residues and more, fostering an effective circular economy.

Our innovation process begins with **research, an open-ended creative ideation phase**, followed by development, where ideas with high potential are transformed into prototypes of future products. Finally, once tested and finalized, the product is produced and marketed to customers. This process cuts across a number of teams and Business Units, including engineering, functional units, sales, and more. Our attention to sustainability has been a successful driver of business growth for Tenova. We are coordinating our **R&D&I efforts across Business Units and Product Lines**, to find integrated, synergistic solutions through collaboration.

Our R&D&I focus areas for 2022-2024 are **energy transition, local environment, process flexibility and efficiency, raw materials and residual valorization, safety, and final product quality**. We have identified how each of these focus areas contributes to the **Sustainable Development Goals (SDGs)**. The SDGs serve as a useful guide for businesses and society to align on to advance sustainable development. To further our impact, we also participate in national, regional and EU working groups on sustainable topics like circular economy and decarbonization to generate projects, roadmaps, and partnerships.

2022-2024 R&D&I Focus Areas and SDGs

Energy Transition		**Process Flexibility / Efficiency (OPEX)**		**Safety**	
Local Environment		**Raw materials / Residual valorization**		**Quality of final product**	

OnlyPlastic

OnlyPlastic, an **EU project funded by the Research Fund for Coal and Steel** started in 2019, demonstrated the possibility to substitute fossil carbon used in EAF steel shops with a Secondary Reducing Agent (SRA) obtained from the residues of waste plastic treatment plants and is compliant with the Technical Standard UNI 10667-17. It overcame drawbacks observed in previous experiences.

Preliminary investigations during OnlyPlastic identified injection as the most efficient way to use SRA, leading Tenova to develop a new family of wall-mounted lances specifically designed to promote iron oxide reduction and slag foaming processes with low-density and high reactive materials.

Tenova's new injection technology demonstrated the sustainability of producing steel by means of alternative carbon carriers without affecting the slag foaming and the EAF process stability with a **lower environmental impact** in terms of CO_2 emissions and reduction of landfilling wastes.

CyberMan4.0

In 2018, **Pomini Tenova** joined a cluster of other European organizations on **CyberMan4.0** — a Cyber-Physical System-based approach for intelligent data-driven maintenance operations applied to the rolling area. The consortium of the CyberMan4.0 project consisted of **five companies and three research institutes** located in Italy, the Netherlands, and Germany. We worked on four use cases: two in Roll Shop operations and two for the production of long laminates.

CyberMan4.0 was designed to develop an **innovative Integrated-Maintenance-Model4.0**, supporting the transition from traditional preventive maintenance to predictive maintenance. To properly maintain equipment, data collection is necessary but not sufficient: in collaboration with Tenova Digital, CyberMan4.0 created a **cloud-based system** that can cross-reference the data of several plants and, using algorithms, predict possible anomalies in order to schedule maintenance at the right moment. The project successfully prevented equipment downtime, resulting in greater efficiency and productivity. It also increased quality by reducing waste, and extended the useful life of cylinders, which reduced the overall use of oil and energy.

Burner 4.0

In 2023 we completed the final activities of EU-funded research project Burner 4.0 under the Research Fund for Coal and Steel (RFCS) grant. Burner 4.0 aimed at leveraging Industry 4.0 technologies to improve industrial combustion systems across many different areas such as design, manufacturing, control and process optimization, operating life, and maintenance. Additive manufacturing, Internet of Things, smart sensors, data analytics for process optimization, and predictive maintenance have been introduced to current burner systems to find breakthrough innovations. Funded by the **European Commission**, Burner 4.0 started by identifying materials and shapes for 3D printing of critical burner components for heat treatment furnaces.

From the R&D activities in Burner 4.0 Tenova developed the first industrial series of its SmartBurner platform. **SmartBurner**'s IIoT framework offers a complete set of process diagnostics, KPIs and KHIs that enable important process parameters like combustion ratio, leakage of switching valves, and combustion quality to be controlled and facilitate burner inspections and maintenance interventions.

HyTecHeat

In 2022 Tenova secured Horizon Europe funding on a project aimed at demonstrating blended green hydrogen / fossil fuel firing in industrial furnaces. Titled HyTecHeat, the projecy aims at leveraging these hybrid heating technologies by evaluating the effects on the quality of steel products, on the refractories and in general on heating processes. Several industrial tests on real industrial burners performed at three European sites will facilitate the hydrogen transition of the steel sector. The demonstrator at TenovaLAB has been selected as representative for hydrogen application in industrial reheating furnaces.

Initially, Tenova will adopt a combination of numerical modelling and experimental testing in order to develop industrial burners able to use hydrogen as a fuel, both pure and mixed with other standard fuels in variable amounts. Furthermore, Tenova will provide an industrial scale example of a combustion system equipped with green hydrogen feeding, in order to validate the technical feasibility of such combustion systems when applied to industrial furnaces.

The industrial equipment currently installed at TenovaLAB's premises allows characterizing full scale combustion systems burning natural gas. The adaptation of the laboratory to hydrogen utilization can be pursued using two alternative approaches: hydrogen trailer or on-site production. The first option has some limitations, mainly concerning the duration of the test due to the limited capacity of the trailer. Therefore, in order to support the development of new hybrid combustion systems the use of continuous hydrogen production unit is necessary. Since the goal is the use of hydrogen produced with renewable electricity (green hydrogen) the adoption of an electrolyser can be considered as a natural consequence. For this project, we're planning on installing a 1.5 MW alkaline electrolyser. The hydrogen produced is then fed to the H2-Ready TLX burner prototype (350 kW) that is installed on the test furnace, able to work in real industrial conditions with natural gas/hydrogen blends and also by using oxygen-enriched air. A combustion control system is installed on a PLC that exchanges control and safety signals with the PLC of the electrolyzer and the pressure loop of the hydrogen buffer. This allows to decouple hydrogen production and hydrogen use, allowing the hybrid combustion system to closely follow the furnace thermal power request, while overcoming the problem of limited turndown of the electrolyzer.

This demonstrator illustrates the technical requirements posed from the utilization of green hydrogen at any industrial site, namely:

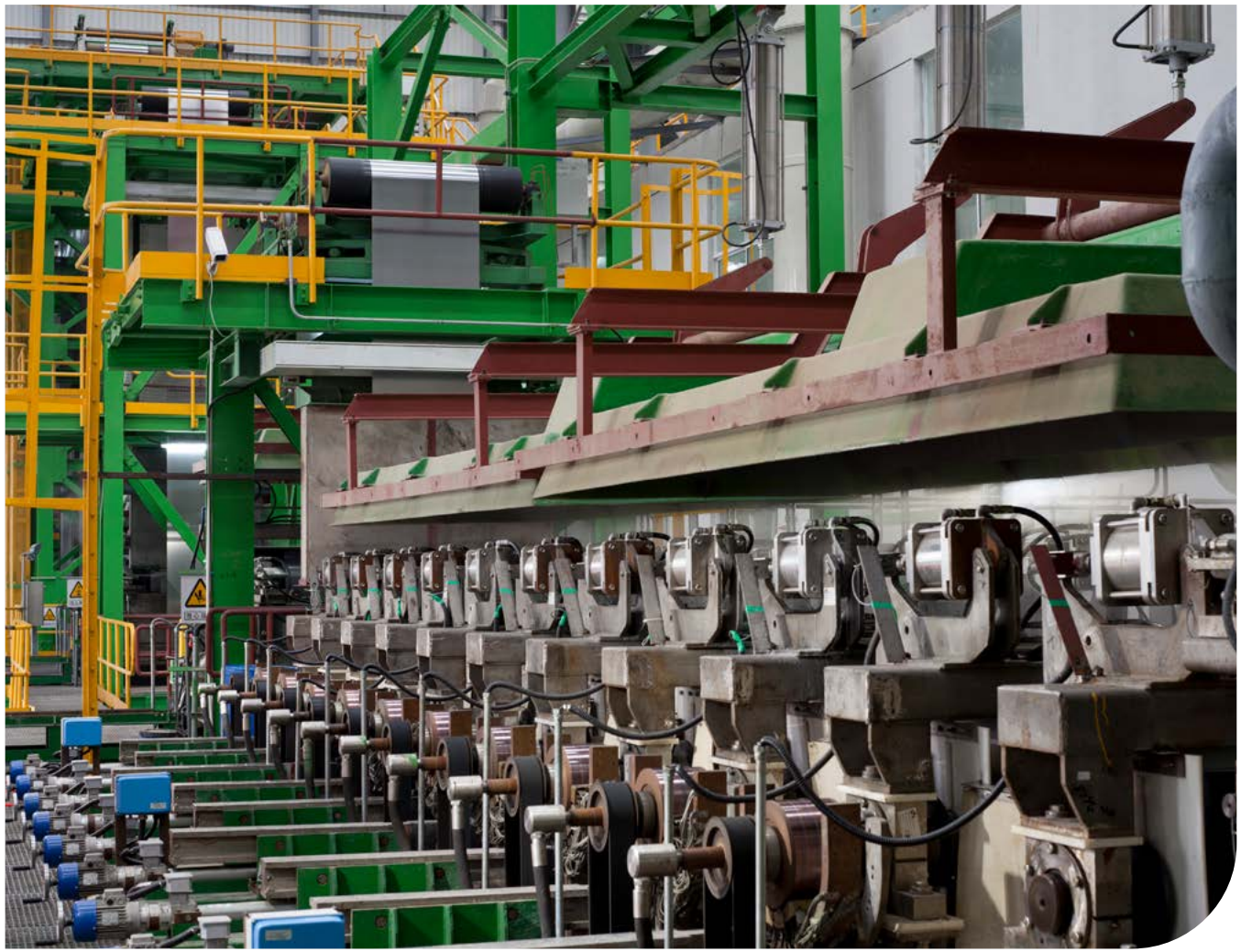
- flexibility of hydrogen production/use;
- proper control of the combustion system with the presence of an electrolyzer for green hydrogen production;
- possibility to store the extra amount of green hydrogen produced for later use.

Insoluble Anode Tin Coating and Chromium-Free Passivation

Due to its anti-corrosive qualities, tin is used as coating in many steel applications, such as food canning and pipes. **Tinning**, however, is the **most complex and sophisticated strip processing line**. In the most advanced lines, tin plating is performed using insoluble anodes where, in older plants, the dissolution of tin results in the generation of large quantities of sludge — with a high loss of tin, a valuable commodity, in the sludge.

Tin coatings are also often passivated using chromium to prevent oxidation. **Hexavalent chromium**, however, can have negative health impacts on workers and its use will soon be banned by the EU.

Tenova's **insoluble anode tin coating process** greatly **minimizes the amount of sludge** produced and, hence, the loss of tin, and its **chromium-free passivation process** provides tin passivation without the harmful effects of chromium. The resulting tin coating also provides more uniform coverage and better edges while more efficiently utilizing the tin. Other benefits are the **reduction of manpower** for anode handling and therefore an increase in safety during operation, the generation of fewer fumes, better process control, more flexible campaigns, and the lowest tin coating thickness reachable on the strip.



2. Digital Transformation

Digital technologies have the potential to revolutionize the metals and mining industries. This is why Tenova has not only integrated digital solutions into many of our technologies but has also assembled a digital strategy and team to stay ahead of the curve. Our strategy places customer value and sustainability at its center, helping us stay focused in this rapidly evolving space. It leverages AI, machine learning and data analytics to increase efficiency and reduce environmental impacts for our clients.

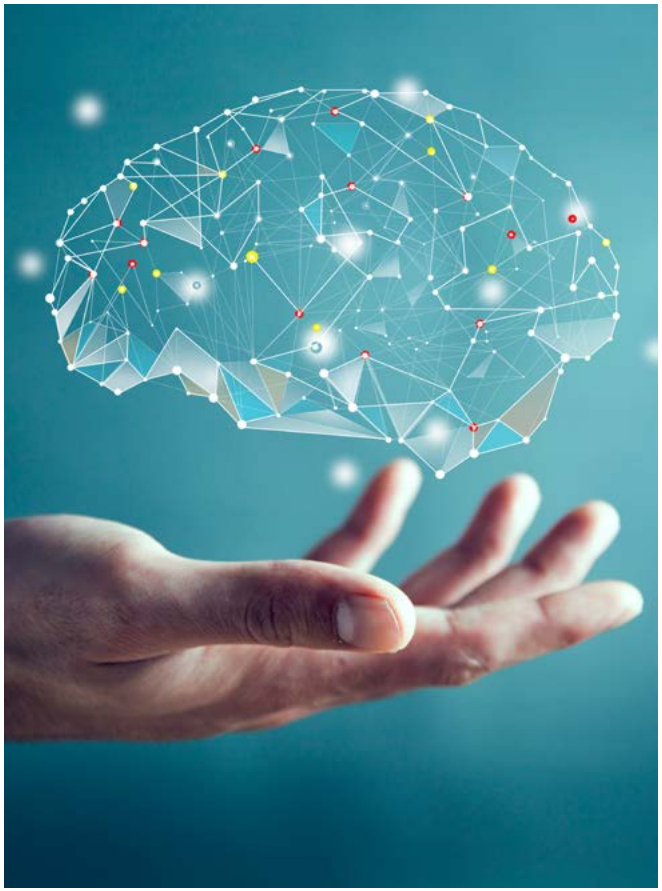
Adopting a Digital Mindset

To continue to optimize productivity through our new hybrid working model, we encourage our employees to adopt a **digital mindset** — seeking digital solutions to solve problems across categories from smart working to Industry 4.0 integration. The ambition of our digital mindset is to **promote a deep cultural change** wherein our teams understand and harness the pioneering modern technologies that are revolutionizing our industries.

We have deployed specific tools and technologies to educate and inform our employees. We have several technological systems in place to support remote collaboration within Tenova and our business partners as well, including the Project Collaboration Portal and the Supplier Portal, all accessible on multiple, user-friendly devices.

Our project management platform provides an accessible central repository of all project information, such as relevant documents, procurement plans, setting Tenova's team for success. For the near future, we are planning to enhance the platform with AI features to reduce repetitive processes, therefore increasing efficiency.

We value the introduction of new tools and support our employees with additional training to familiarize them with these innovations, enhancing their connection with one another, while also emphasizing the importance of protecting sensitive information through high cybersecurity awareness and a thorough understanding of Tenova's procedures and guidelines. We have also successfully realized the **first pilot project using GenAI** (generative artificial intelligence). The adoption of such a novel technology, which is advanced enough to be used in industrial environments, will enable our employees to optimize their daily work and to focus on activities with real added value.



"Acciaio_4.0" Plant of the Future

The **Cluster Fabbrica Intelligente**, or Italian Smart Factory Cluster, is an association sponsored by the Italian Ministry of Scientific Research with the aim of implementing a strategy based on research and innovation for the competitiveness of Italian manufacturing. To promote the development of digitally-enabled factories, the Cluster launched its Lighthouse Plant challenge. Lighthouse Plants are factories that are already operational and ready to become smart factories by using Industry 4.0 technologies like big data, IoT and artificial intelligence.

Tenova **ORI Martin's "Acciaio_4.0"** plant was one of four plants accepted as a Lighthouse. "Acciaio_4.0" aims to develop a **Cyber Physical Factory** that will allow the vertical, horizontal, and transversal integration of the entire steelmaking process, making it more efficient, flexible, and sustainable. As the industrial technological partner, Tenova designed innovative models of integrated processes for the plant, using smart sensors (IoT) and gathering data in cloud systems to develop machine learning applications, remote support, and predictive maintenance, taking into consideration environmental sustainability, people's safety and data security.

In 2023, the project was concluded with the deployment of a list of digital packages in the ORI Martin's steel plant. The image below shows the benefits of the digital packages developed and deployed.

Production cost reduction

Traceability & sustainability of the production process

Greater flexibility

Increased safety in the workplace

Support Client Engagement

In addition to the digital features embedded in our products, we want to provide our clients with the best possible service, so we have created several systems to help employees communicate effectively with clients. Customers have access to a **Tenova Digital Portal** where they can request support for specific products and order spare parts. The portal is regularly updated with new features. Some of the proprietary digital tools we have developed include:

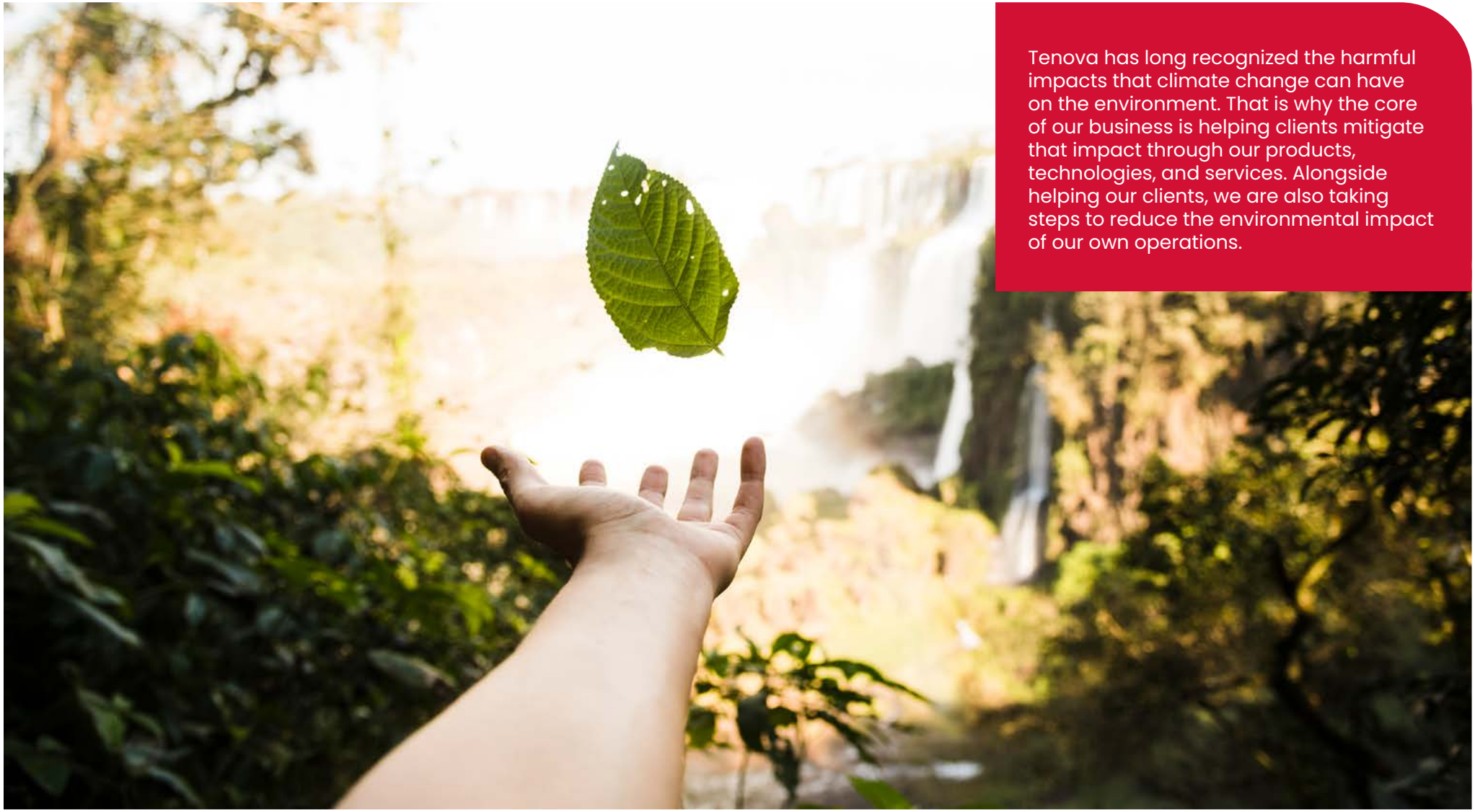
- **Tenova IIoT Platform** is the IIoT platform developed in partnership with Microsoft, which facilitates communication with our customers. The purpose of the platform is to retrieve plant data and analyze them to develop new services and AI applications which help customers use and maintain their equipment;
- **Tenova EDGE** is the field gateway developed by Tenova which allows to connect our customer's plant to Tenova IIoT Platform in a standard and secure way. This EDGE device has also the capability to host and automatically manage the update of developed machine learning models and AI applications;
- **Tenova adVISOR**, a virtual assistant that provides suggestions on product maintenance and operation. It can be used on a mobile device and provides real-time updates. The tool's remote assistance feature, available on mobile and wearable devices, offers support to field operators;
- **Tenova Catalog Creator**, which enables customers to easily select spare parts with fewer mistakes by connecting to the customer's portfolio database, accurately identifying the correct part.

As well as projects related to the Digital Transformation of Processes, Tenova strives to develop digital solutions that reduce the environmental impact of our customers' plants, and launch these solutions on the market.

Notable launches have included the inauguration of TenovaLAB, established to conduct experiments and R&D in burner development, facilitating the completion of the Smart Burner platform. Additionally, the adoption of the Tenova IIoT platform enables the application of Tenova's proprietary mathematical models, including those used for the thermal simulation of reheating furnaces. This innovative use of models also allows us to provide new services to our customers: for instance, the thermal model of reheating furnaces could be used by our customers as simulator in order to gain insights on possible improvements in the equipment operation.

One of the new features introduced to the Tenova IIoT Platform is the **Emission Impact Dashboard**. This tool is designed to track the emissions produced by the cloud services utilized by the platform. Consequently, it enables the monitoring and demonstration of the environmental impact of Tenova's products and technologies across the entire value chain, extending beyond the equipment installed at customer sites.

3. Environmental Impact from Our Operations



Tenova has long recognized the harmful impacts that climate change can have on the environment. That is why the core of our business is helping clients mitigate that impact through our products, technologies, and services. Alongside helping our clients, we are also taking steps to reduce the environmental impact of our own operations.

3.1. Our emissions and energy use

26%

2024 Goal

Reduction of Scope 2 emissions (market-based) of **450 tCO_2e** by 2024 (*)

(*) equivalent to a 26% reduction (baseline 2022)

Tenova's own energy consumption and direct CO_2 emissions stem largely **from our corporate offices and a few productive sites** and laboratories located in Italy (Castellanza), Poland, Canada, and Israel. Due to the minor scale of our in-house production, **our direct carbon impact is negligible**.

In this report our primary energy consumption and direct CO_2 emissions are disclosed, in particular those relating to our **main Italian offices, located in Castellanza and Genoa**, as well as the **production location in Castellanza**.

We currently do not measure or disclose environmental data for our sites in Poland, Canada, or Israel, although Tenova will evaluate structuring a monitoring process to also gather this data in the coming years.

In order to reduce our direct CO_2 emissions, we have committed to reducing our energy and gas consumption across all of our Italian sites and HCFC plants (cooling systems). To achieve this, in 2018 we set up an energy measurement system that monitors utility usage at our most energy intensive site in Castellanza, as well as an energy and gas consumption working group to identify opportunities to reduce our usage.

During 2023, we undertook several energy efficiency initiatives including:

- Investment approved for the complete renovation of Avancorpo and Crono buildings (also from an energy efficiency perspective). The Avancorpo renovation will be completed in 2024, while Crono by 2026;
- Impact analysis, in terms of carbon footprint, of purchasing a nitrogen production plant instead of the delivery of cylinder packages;
- Replacement of lamps with LEDs;
- Monitoring and mitigating HCFCs leaks;
- Encouraging employees to work from home two days per week to reduce transport emissions;
- Encouraging employees to adopt sustainable behavior.

Looking ahead, we have also invested in the development of a 980 kW new-generation photovoltaic PV system for our production site in Castellanza that generates around 1 MWh/year of electricity. Since September 2023, the 9,000 sqm solar field installed on the roof of the Pomini workshop has been running smoothly.

We have chosen to deploy 1,781 superior performance and highly reliable high-efficiency monocrystalline silicon panels. The system, with a power of 980 kWp, will be able to generate up to 1000 MWh annually, which is around 30%, accounting for close to 80% of the factory's requirements.

The plant is currently producing more than its theoretical output: considering the four-month period (Q4) from September to December, we have produced approximately 247 MWh, compared to an approximate theoretical output of 198 MWh.

90% of the energy produced by the solar field will be used on the campus, while the remaining 10% will be sold back to the grid. The solar field is set to power our forthcoming electrolyzer which will create hydrogen from water for industrial applications, further reducing the impact of this green hydrogen source. We are also considering sustainable building approaches as we renovate older facilities, in particular our Castellanza site.

Our Energy Use[1]

GRI 302-1 Energy consumption within the organization

	2022		2023	
	Total	Total in GJ	Total	Total in GJ
Fuel consumption from non-renewable sources	**-**	**16,284.6**	**-**	**14,349.8**
Fuels used for productive purposes	**-**	16,153.7	**-**	14,190.9
Natural gas	449,653.0 mc	16,135.7	391,923 mc	14,183.7
Diesel	500.0 litres	18.0	202 litres	7.2
Fuels used for fleet vehicles owned by the organization or long-term leases (only company use)[2]	**3,645.0 litres**	**131.0**	**4,467 litres**	**159.0**
Diesel	3,645.0 litres	131.0	4,467 litres	159.0
Electricity consumption	**3,672,192.0 kWh**	**13,219.9**	**3,786,477.0 kWh**	**13,631.3**
Electricity purchased	**3,672,192.0 kWh**	**13,219.9**	**3,501,157.0 kWh**	**12,604.2**
Purchased electricity from non-renewable sources	3,672,192.0 kWh	13,219.9	3,501.157,0	12,604.2
Electricity produced	**3,672,192.0 kWh**	**13,219.9**	**285,320.0 kWh**	**1,027.2**
Electricity self-generated from renewable sourcessources	**0**	**0**	**285,320.0 kWh**	**1,027.22**
Total energy consumption within the organization	**-**	**29,504.5**	**-**	**27,981.2**

When looking at the fuel consumption for production purposes in 2023, there was a decrease, highlighting Tenova's efforts in this field. However, due to the increase of business travels for on-site tasks, fuels used for fleet vehicles owned by the organization has grown.

1 Data related to energy consumption and Scope 1 and 2 emissions refers to Tenova's Castellanza and Genoa sites

2 Data related to fuel use for fleet vehicles owned by the organization or leased long-term (mixed use) is currently not available

Our CO_2 Emissions

GRI 305-1 Direct (Scope 1) GHG emissions
GRI 305-2 Energy indirect (Scope 2) GHG emissions

	Unit of measure	2022	2023
Scope 1 GHG emissions	tCO_2eq	278.9	247.7
Scope 2 GHG emissions – location based[1]	tCO_2eq	902.3	988.3
Scope 2 GHG emissions – market based[1]	tCO_2eq	1,676.6	1,160.1

Our other air emissions[2]

GRI 305-7 Nitrogen oxides (NOx), sulfur oxides (SOx), and other significant air emissions

	Unit of measure	2022	2023
Particulate matter (PM)	kg	5.8	4.4
Chrome[3]	kg	<0.01	0.01

1 A location-based method reflects the average emissions intensity of grids on which energy consumption occurs (using mostly grid-average emission factor data). A market-based method reflects emissions from electricity that companies have purposefully chosen (or their lack of choice).

2 Data related to significant air emissions refers to Tenova's Castellanza site. Data based on chemical analysis at the emissions. The monitoring of air emission is not continuous, therefore the available data was used to estimate total emissions during the year.
3 0.0132 kg in 2023 and 0.0000528 in 2022

3.2. Waste and Water

In addition to energy and electricity, we strive to **reduce our use of other resources** including water, as well as minimizing our generation of waste.

Our **waste collection and disposal** comply with all local regulations. Given that most of our operations are in office buildings, with a few small manufacturing locations, most of the waste we produce is non-hazardous. Our industrial waste is managed by authorized third-party companies.

We are committed to finding ways to **reduce the amount of waste we generate**, repurposing waste in-house when possible, and recycling as much as possible in order to minimize waste sent to the landfill. We have increased the number of waste collection points in our office locations and all employees receive training on correct separation of waste to improve landfill diversion. We also compact our waste to reduce its overall volume. Additionally, we have installed **water refilling stations** and offer reusable, dishwasher-safe cups to encourage the use of reusable bottles over single-use plastic ones. Since installing the stations in October 2022, we have prevented the use an estimated 6,500 plastic bottles.

We are currently exploring ways to improve the separation of waste types. Looking ahead, we aim to conduct in-depth research on our waste's pathways downstream to further improve our diversion rate.

Waste Generated[1]

GRI 306-3 Waste generated

	Unit of measure	2022	2023
Hazardous waste	tons	62.5	118.7
Non-hazardous waste	tons	179.2	197.5
Total weight of waste generated	tons	241.7	316.2

GRI 306-4 Waste diverted from disposal

	Unit of measure	2022	2023
Hazardous waste diverted from disposal	tons	53.0	110.2
Recycling	tons	53.0	110.2
Non-hazardous waste diverted from disposal	tons	179.0	194.1
Recycling	tons	179.0	194.1
Total weight of waste diverted from disposal	tons	232.0	304.3

GRI 306-5 Waste directed to disposal

	Unit of measure	2022	2023
Hazardous waste directed to disposal	tons	9.55	8.55
Incineration (without energy recovery)	tons	0.1	2.7
Landfilling	tons	9.4	5.8
Non-hazardous waste directed to disposal	tons	0.2	3.4
Landfilling	tons	0.2	3.4
Total weight of waste directed to disposal	tons	9.7	11.9

1 Data related to waste generated refer to Tenova's Castellanza and Genoa sites

CASE STUDY

Improving Coolant Filtration

In 2022, Pomini Tenova piloted a process to more effectively separate solids and liquids during the grinding process.

Coolant-lubricant used during the grinding process produces a waste byproduct that is filtered so it can be recirculated and reused. The filtration process requires a magnet and paper filter which separate solids from liquids. We tested using a magnet of 9,000 g strength, versus the existing 850 g magnet. It provided roughly double the separation capacity, extending the usable life of the coolant-lubricant. Additionally, the waste sludge that results from the filtration process was tested as a secondary raw material input for use in foundry applications. Its use significantly reduced residual moisture in briquettes. This innovation provides not only an environmental benefit by extending the useful life of coolant-lubricant but reduces costs related to the disposal of waste sludge.

We are currently pursuing a circularity project in partnership with **Sfridoo** to analyse the feasibility of an industrial briquetting process involving the installation of a pilot briquetting machine at the Castellanza workshop. We will then proceed to the feasibility of the project for implementation at customer sites.

We manage our water use in compliance with current legislation.

At our Castellanza site, water is withdrawn from on-site wells to load fire extinguishers, irrigate landscaped areas, and load hydraulic power units to test roll grinders. If water is mixed with oil or other solvents, it is discharged temporarily into a tank and subsequently disposed of as wastewater, following regulatory guidelines. For our Genoa and Castellanza sites, water for daily employee use is withdrawn from the aqueduct and discharged into the sewer. Water withdrawn from wells and discharged water are monitored through chemical analysis on an annual basis. Wastewater is monitored through chemical analysis every six months. Data is shared with management every year. In 2022, a drought in Italy required us to replenish our site wells, resulting in an increase in water use compared to the previous year. As this emergency has subsided, in 2023 water use has returned to the average levels, even showing a moderate reduction in comparison to 2021, thus aligning with our environmental commitments.

Water Use[1]

GRI 303-3 Water withdrawal
GRI 303-4 Water discharge
GRI 303-5 Water consumption

	Unit of measure	2022	2023
Total Water withdrawal	Megaliters	41,169.00	24,804.00
Groundwater – Freshwater (≤1,000 mg/L Total Dissolved Solids)	Megaliters	27,410.00	15,160.0
Third-party water – Freshwater (≤1,000 mg/L Total Dissolved Solids)	Megaliters	13,759.00	9,644.0
Total water discharge	Megaliters	9,064.00	9,733.0
Third-party water – Freshwater (≤1,000 mg/L Total Dissolved Solids)	Megaliters	9,064.00	9,733.0
Total water consumption	Megaliters	32,105.00	15,071.0

1 Data related to water withdrawal, consumption and discharge refers to Tenova's Castellanza and Genoa sites, which are not located in water stressed areas (Source: World Resources Institute, Aqueduct Water Risk Atlas, www.wri.org/our-work/project/aqueduct). During 2023 and 2022 there were not significant changes in water storage.

Considering the climate impact and waste management of Tenova's operations, in 2023 the company committed to:

- the **extension of the Energy Metering System** to improve the monitoring of utility consumption, already achieved by 2023 (e.g., monitoring of calories absorbed by water pre-heating processes for canteen food preparation, monitoring of new FTV production and feeding back into the grid of non-self-consumed energy);
- the **renovation of a building** currently in class G (Crono) by 2026;
- the **construction site for an H_2 electrolyser** for research and development activities (fed in particular on Saturdays and Sundays by production surpluses from the photovoltaic plant) by 2024.