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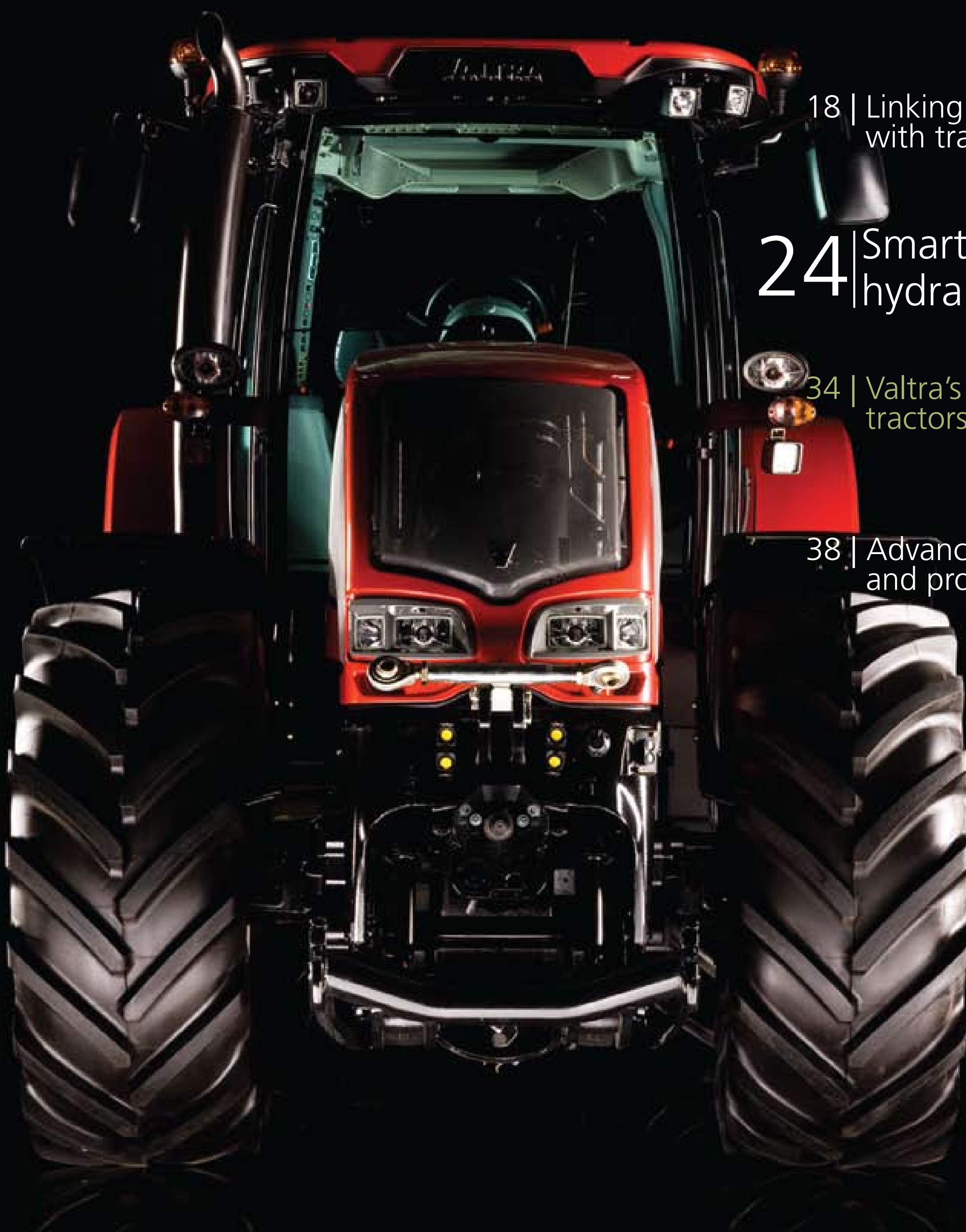
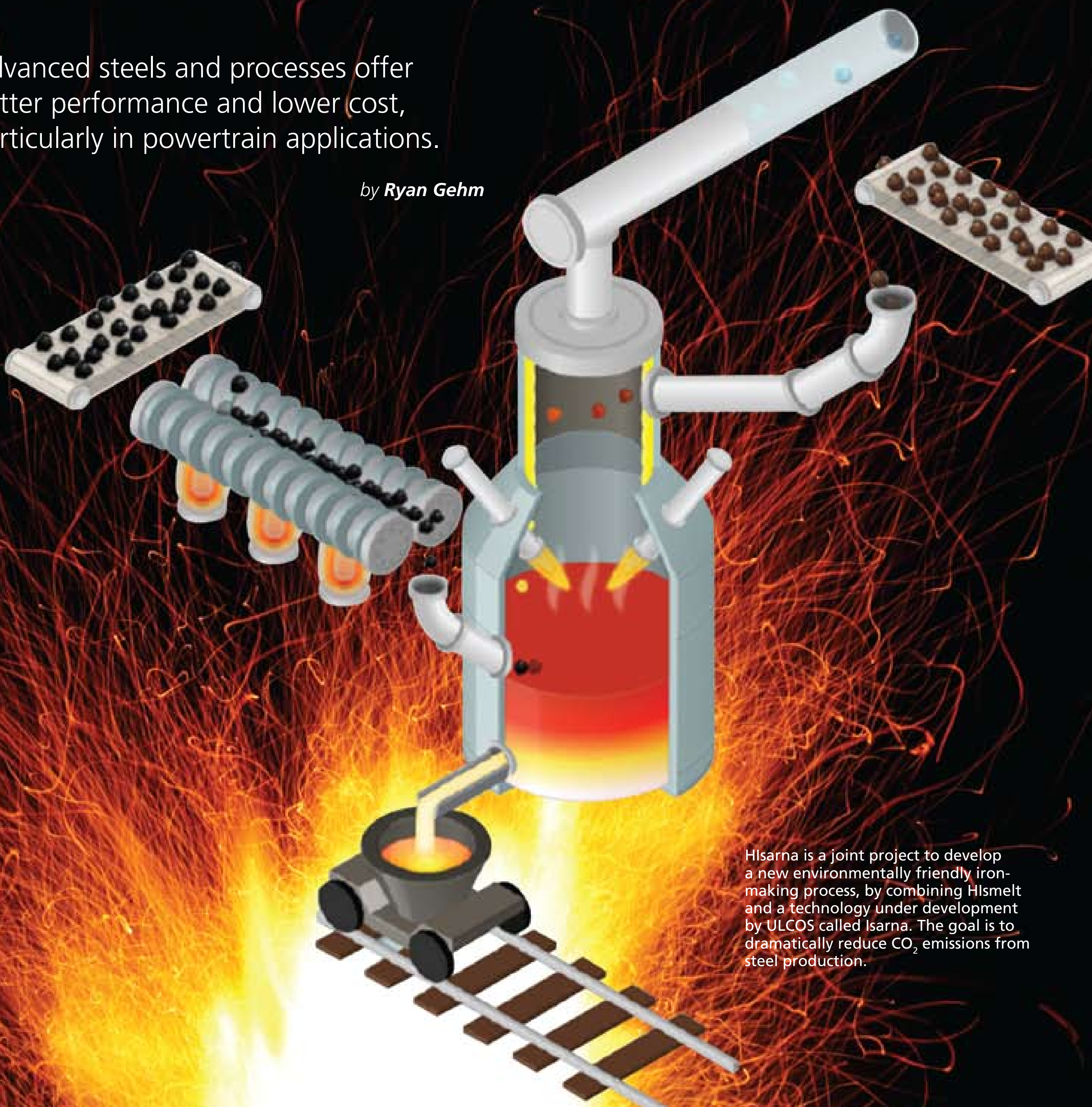


Steel still king

Advanced steels and processes offer better performance and lower cost, particularly in powertrain applications.

by ***Ryan Gehm***



HIsarna is a joint project to develop a new environmentally friendly iron-making process, by combining HIsmelt and a technology under development by ULCOS called Isarna. The goal is to dramatically reduce CO_2 emissions from steel production.

Stricter emissions requirements translate into much higher pressures, which means the steel used for fuel-injection systems, for example, must have higher toughness and better fatigue characteristics. Shown is a diesel fuel injector body manufactured from parapremium carburizing steel supplied by Timken.

Microalloy steels have made significant inroads in components such as crankshafts.

The old motivational saying, "If you're not improving, you're getting worse," can very easily be applied to the materials development world. Design engineers, metallurgists, tribologists, process personnel, and others are constantly working to offer better performance, higher quality, lower overall cost, and simpler processing from their products; because if they're not, a new material or a different grade from a competing company is always waiting to add new applications to its resume.

In the off-highway industry, steel is by far the material of choice. But still, competition exists. "There's not a lot of drive to reduce weight or go to ultra-high strengths [in off-highway], so usually one steel is competing against another," said Mike Burnett, a technologist at **Timken**. "Most applications, steel is the incumbent and it has been for many years, and we're just improving upon what has been the historical material in the application."

Steel is widely used for applications ranging from steering knuckles to ground-engaging equipment to structural-type members. "[But] we see more requirements, more drive for advanced materials in the whole powertrain," he said.

Driving the demand for more advanced steels in the powertrain are fast-approaching, stricter emissions requirements, as well as the desire for improved fuel economy and increased power density—being able to deliver more power in a more compact space. For Timken, that means making advanced steels for such critical areas as fuel-injection systems.

"As far as true advances [in steel], it would probably be in the injection systems where emissions requirements translate into much higher pressures," said Craig Darragh, Senior New Business Development Technologist, Timken. "So you have in the injection system very clean steels [*i.e.*, no intergranular oxidation] and/or shape-controlled steels with higher toughness and better fatigue characteristics."

"We're constantly improving those characteristics, both from an alloy standpoint and internal cleanness standpoint," added Burnett. "They're going to higher and higher pressures, which puts higher and higher stress on these components, and they need better and better steels."

Cost always a consideration

One competitive material to steel is cast iron, notably in cylinder liners. But steelmakers such as Timken are making a push to claim that application area as well.

"The challenge there is steel is more expensive, so if they have the design capability, the easiest way is to design in cast iron to keep the cost down," said Burnett. But the door may be opening for steel due to increased performance requirements. "In some applications, they're reaching the limits of cast iron so they have to move into steel," he continued. "We have developed recently…some cylinder-liner grades that show some advantages with regards to being able to withstand the higher pressures associated with these power cells, with the increased emissions requirements."

Reduced cost—as well as improved strength and durability—is one reason new grades of microalloy steels "are winning some of the battles against cast-iron components," said David Anderson, Director for the Automotive Applications Council and of Long Products for the **American Iron and Steel Institute** (AISI).

Microalloy steels have been around for decades, and as the technology has advanced it has made significant inroads in components such as crankshafts, steering knuckles, and hydraulic cylinder liners. "They're generally used in applications where the strength levels are lower than what you would have in gearing," noted Darragh.

Simplified manufacturing and reduced processing costs are driving this trend. "Microalloy steels are produced to give you a nice fine-grain microstructure during fabrication. It helps in increasing the toughness of the material and also in manufacturing in that you could eliminate

Inner bearing race before

Timken has designed a line of alloy steels specifically for vacuum-carburizing heat treatment, which results in a final product that is visually and metallurgically clean.

Inner bearing race after

some process steps like heat treatment," said Anderson. They are designed to provide the properties in the as-forged or as-processed condition, as opposed to having to do a full quench-and-temper or carburizing operation.

For steels that are heat treated, an industry trend is to move away from traditional gas carburizing to low-pressure vacuum carburizing, according to Burnett. Claimed benefits of such a move—in addition to reduced costs—are cleaner processes, improved product consistency, and reduced cycle times.

"In many instances, the customer is asking us to develop steels for vacuum carburizing that can also be used in conventional gas carburizing because they are going to maintain their current operations as well as their newer equipment," said Darragh, noting that vacuum carburizing steels are in the process of being evaluated for use in off-highway equipment, particularly differential applications, and are finding considerable application on-road in Class 8 trucks.

Designing a better material

Gearing is another area where advanced steels are flourishing. One company that develops such gear steels is **QuesTek Innovations** LLC. The Evanston, IL-based materials solutions company applies its proprietary Materials by Design R&D process to the design and development of not only new iron-based alloys, but also those based on nickel, aluminum, titanium, and copper.

"Simply stated, QuesTek's Materials by Design methodology uses computer technology to virtually rearrange (*i.e.*, model and analyze) atoms of an alloy to control and predict the properties of a material without actually making alloy melts through a typically exhaustive trial-and-error process," explained Charlie Kuehmann, President and CEO of QuesTek. "To do so, QuesTek uses proprietary Computational Materials Dynamics software and platforms, which include a suite of detailed thermodynamic and kinetic databases that fuel multi-level models to predict microstructures and associated material properties."

While the technology's previous capabilities dealt primarily with strength and ductility, "we now have better modeling capabilities for these materials in fatigue, corrosion resistance, and other aspects of their performance," Kuehmann said. "With the modeling, we can now get to the point where we can integrate with the design engineer and go back and forth…to come up with a better part."

Another aspect of the modeling technology is helping to balance costs—process cost, raw material cost, as well as life-cycle cost—with a material's performance characteristics. For example, "can you take a less expensive material like a steel and get it to work like a titanium? Can you get titanium to work using cheaper raw materials and processing routes like castings to be able to replace, in some cases, more expensive steels?" Kuehmann posed. "So you can kind of bring the higher-cost materials down in cost and you can bring lower-cost materials up in performance to try to drive a better trade-off."

The process typically reduces material development costs and timelines from 15 to 20 years to just a few years, he said, noting that QuesTek's Ferrium C61 carburized steel was designed with a single prototype. C61 has a high-strength/high-toughness core to allow for weight reduction or increased power density of components compared to those made of traditional carburized 9310 steel, for example.

C61 is currently used to make V091 ring and pinions in transmissions for SCORE 1600 class off-road racing cars.

"The next development of the gear steels is an alloy called C64, which is a higher-performance variant of C61. It has the opportunity to significantly reduce the size of the transmission," said Kuehmann. "In helicopters, we're targeting about a 25% reduction in weight of the transmissions, and I think similar benefits could be seen in off-highway or automotive." C64 is in the specification development stage now, and is expected to be market-ready in the next year or two.

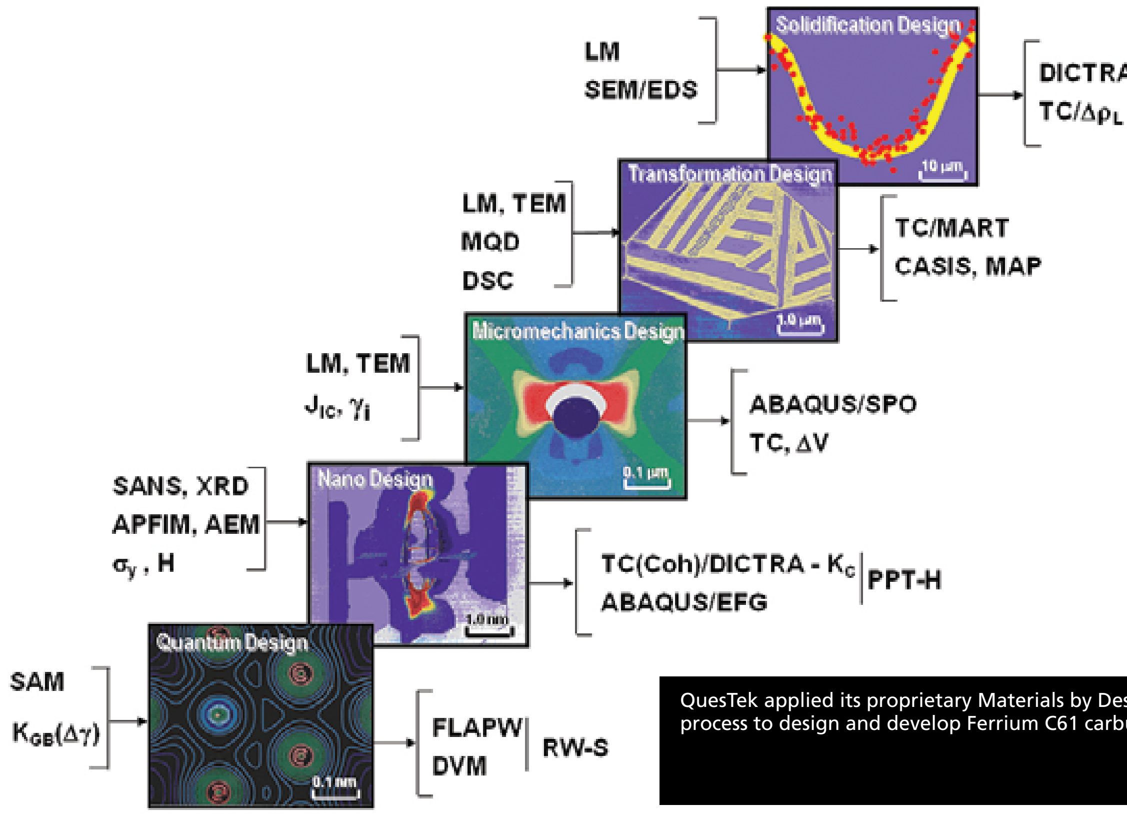
Another offering, Ferrium S53, is an ultra-high-strength, corrosion-resistant steel targeted primarily for aircraft landing gear currently. It could conceivably find application in off-highway, Kuehmann said, particularly areas that may have issues with stress corrosion cracking or possibly in the engine due to the material's high thermal resistance.

"In off-road, I think that in many cases you do have to worry about corrosion. Some of those vehicles operate in pretty extreme environments," he observed, but such alternative possibilities largely depend upon its licensees, **Carpenter Technology** and **Latrobe Specialty Steel**, and their customers' interests.

Sustainable steel

Steel is the most recycled material in the world. Steelmaker **Nucor** Corp., which claims to be North America's largest recycler of the material, keeps a running tally on its website of the amount of scrap recycled this year: as of Jan. 30, that number was already well above 1.6 million ton (1.45 million t). In addition to conserving numerous thousands of tons of iron, limestone, and coal, the recycling efforts had resulted in enough electricity conserved to power more than 1200 average homes for a year, according to the real-time statistics.

Nucor proudly promotes its environmental stewardship and the projects that advance the cause, as do a growing number of other companies. One such project for Nucor, with partners **Rio Tinto** Ltd., **Mitsubishi** Corp., and China's **Shougang** Corp., is a HIsmelt plant in Kwinana, Western Australia, which uses a process that has the potential to "significantly" reduce greenhouse gas emissions compared to a facil-



QuesTek applied its proprietary Materials by Design R&D process to design and develop Ferrium C61 carburized steel.

ity using more conventional processes.

Last fall, mining and exploration company Rio Tinto and **ULCOS**—a consortium of nearly 50 European companies including major steelmakers such as **ArcelorMittal**, **Corus**, **ThyssenKrupp**, and **Voest**—agreed to collaborate on a project to develop a new environmentally friendly iron-making process, based on the combination of HIsmelt and a technology under development by ULCOS called Isarna.

Formed in 2004, ULCOS (Ultra Low CO_2 Steelmaking) aims to reduce CO_2 emissions from steel production by at least 50% via new technologies. The Isarna process is based on direct smelting of iron ore fines using a smelt cyclone in combination with a coal-based smelter. All process steps are directly hot-coupled, avoiding energy losses from intermediate treatment of materials and process gases. The HIsmelt smelter uses coal and oxygen-enriched air in combination with a fluidized bed iron ore preheater to produce liquid iron.

QuesTek's high-strength/high-toughness C61 alloy is available for power transmission applications. It is widely used in SCORE 1600 class off-road racing car transaxles (ring and pinion shown).

The joint project, called HIsarna, aims to develop a new process by operating the combination on pure oxygen, which facilitates CO_2 capture and storage.

"The main feature of the process is that it uses the raw material coal and iron ore almost 'as mined,' while the blast furnace route needs pretreatment steps for the coal and the ore," explained Koen Meijer, ULCOS Project Coordinator for Corus. "The coal is processed to coke and the ore to pellets and/or sinter; these steps are eliminated by Isarna."

In addition to lower operating costs, another major benefit of the process is "increased raw material flexibility compared to the blast furnace, use of non-coking coals, and wider range of ores—for instance, ores with phosphor and zinc and use of plant reverts," Meijer noted. "Due to increased energy efficiency, [the Isarna process results in a] 20% reduction in CO_2 emissions per ton of hot rolled coil. If applied in combination with carbon storage, the reduction can be as high as 80%."

A pilot plant rated at 65,000 t (72,000 ton) per year will be built at **Saarstahl** (an ULCOS participant) in Völklingen, Germany. The facility is due to start operations in early 2010, followed by a three-year pilot testing phase. According to Meijer, the HIsarna process should be ready for high-volume use by 2015. ***sohe***