White Paper Green Steel Swiss Steel Group (SSG)

The road to climate-neutral steel production and beyond

Swiss Steel Group (SSG) is launching «Green Steel», an initiative for ecologically produced low carbon steel. Decisive for customers and the public is that all measures are coordinated and transparent. «Green Steel» is thus not only a tool that gradually and systematically helps reduce the emissions of the entire Group. It is also intended to help customers and partners and encourage them to do more to mitigate climate change. The tasks of the SSG production sites and scientific labs are thus massively expanded with Green Steel. Green Steel makes them platforms of technology, experimentation, and innovation whose horizon and impact extends far beyond the steel industry.

If decarbonization isn't possible for steel, it isn't possible anywhere. Without measures being taken in the steel industry, decarbonization of global commodity flows is not possible and climate change cannot be stopped. Steel as a material contains a very high percentage of what is known as "embodied energy" that is part of almost every product and many, many services, and thus their CO2 footprint. Embodied energy is the "gorilla in the room", the monster that no one wants to see. In reducing the Group's own footprint and its more accurate documentation within the framework of the groupwide initiative "Green Steel", Swiss Steel Group (SSG) aims to reduce emissions to near zero. These efforts, however, are also meant to encourage customers and serve as a call to cooperate with science and the public. This will intensify the effect of efforts beyond the steel industry.

Blast furnace route versus electric arc furnace route

The steel industry distinguishes between two production routes, the primary and secondary route, respectively, using the blast furnace and the electric arc furnace route. In a blast furnace route, mined iron ore is melted into pig iron and ultimately into steel. This process produces new steel of the highest quality grades, often with very high CO2 emissions. The reducing agent is primarily bituminous coal although tests with hydrogen are currently being conducted. While fossil coke as a reducing agent produces CO2 as a waste product, steam is produced when hydrogen is used instead. The secondary route with the electric arc furnace works exclusively with steel scrap. This pathway thus uses considerably less energy and emits much less CO2 than the primary route. The smelting process takes place in electric arc furnaces and is thus much simpler to decarbonize than the blast furnace route. On the one hand, the main source of energy is electricity and, on the other, the process uses much less energy and needs fewer energy-intensive intermediate stages.

SSG has decided to pursue the electric arc furnace route exclusively in their steel mills. Their emissions are thus far below the industry average. This route is well-established and proven, especially given the fact that steel is the material most frequently recycled worldwide. Still, there are also major challenges on the electric arc furnace route. For a long time, it was not possible to produce all steel grades due to unavoidable trace elements. The available scrap volume is not always the same, and quality scrap needed to produce a precise steel grade is often lacking. Quality or new scrap is the single-origin scrap stemming from pressing and fabricated sheet works like the gratings produced from large steel strips when individual parts are punched out. Quality scrap, however, is also obtained from chips produced by machining processes in manufacturing such as cutting, turning, drilling, and sawing. In some machining

processes, up to 90% of the starting material winds up as so-called new scrap. This scrap is highly sought after, expensive and will be even more valuable going forward because more and more of it is being used to control the quality of steel in the furnace.

A decisive and very complex part of the electric arc furnace route is thus scrap logistics. Compared to the blast furnace route where a single contract with a mining company can ensure the supply of raw material for years on end, the electric arc furnace route requires an elaborate collection and sorting system in cooperation with local companies and scrap dealers who have to deliver scrap in increasingly better quality with ever more elaborate and more expensive methods. A major ecological advantage of the electric arc furnace route is that the raw material can often be procured within an 80 to 100-kilometer radius. Transport routes are short, and the corresponding emissions are almost insignificant. On the blast furnace route, European companies import iron ore primarily from Brazil and coal from Australia or Russia.

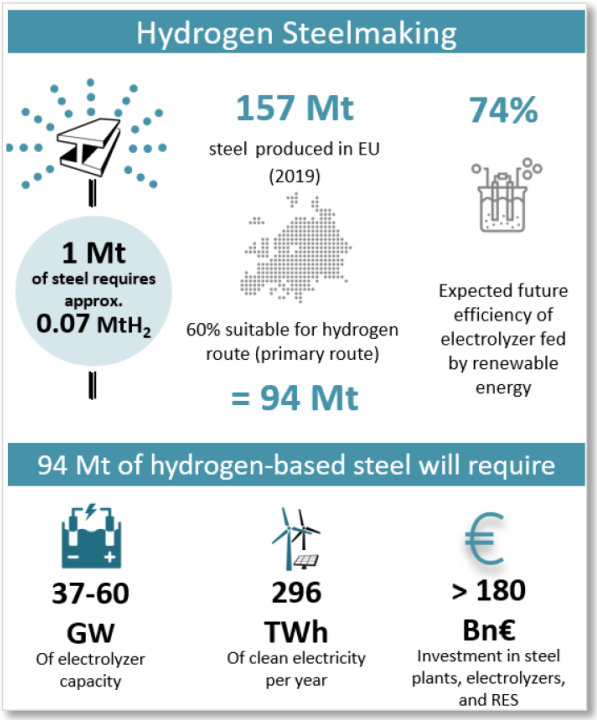
Scope 1: Hydrogen instead of natural gas

SSG is focusing on three strategic approaches in production processes. Each enhances the effect of the other two and together they drastically reduce the impact on the climate.

The Scope 1 reduction consists of the replacement of natural gas, particularly in rolling mills. Hydrogen, synthetic gases, biomethane or synthetic methane are to be used in the medium term. Except for biomethane, all these gases are produced by means of more or less sophisticated intermediate stages from electricity which in future is to be available at low cost or even negative prices when generated by hydroelectric installations, wind turbines and photovoltaic systems.

The electrolyzer power currently available in Europe to produce green hydrogen is only 200 Megawatts (MW), which is equivalent to the output of two run-of-river hydroelectric power stations on the High Rhine between Lake Constance and Basel. Measured relative to future demand, that is still almost nothing, and the extension of expensive installations is proceeding very slowly. Additionally, for the moment at least, it does not seem that electricity is constantly dropping in price, and green hydrogen would then automatically be generated. Due to breakdowns in French nuclear power plants and gas shortages on the spot markets prior to the events in Ukraine, the electricity prices in winter 2021/22 exploded on the European sport market. There was no capacity available to produce hydrogen and the price would have been exorbitantly high.

Green hydrogen has a lot of problems to solve. The discussion, however, usually centers only on mobility. It is often forgotten that there are much more pressing problems to which there is no solution but hydrogen. This includes the decarbonization of the steel industry. Yet low production capacities and presumably continuing high prices for hydrogen set off against high demands. The steel industry with appropriate public engagement need to cooperate with other industries and point out where the priorities in hydrogen policies need to lie. (Chart: Liebreich Associates)



The decarbonization of the European steel industry alone requires an electroyzer capacity of 37,000 to 60,000 MW to produce green hydrogen. Current installations are at 200 MW. Added to this are the demands of the chemicals industry, fertilizer production and many other industries in which there is no alternative to hydrogen in production processes. (Chart: European Parliamentary Research Service)

Yet even if nuclear power plants are up and running, the wind is blowing and the sun shining, it doesn't automatically mean "free power" for hydrogen production. Prices fall in this case dramatically, but power plant operators have learned to stabilize markets by deliberately shutting down power plants and wind parks in such a way that prices don't plummet. Power that could be generated from hydrogen will thus probably have a price above zero. This price will be at least as high as the operating costs of producers of electricity from renewables which have been written off. This price threshold is currently € 30/MWh (3 Eurocents per kWh) for amortized wind turbines. The installations are dismantled when compensation for electricity fed into the grid falls below this price. It must be clear to the steel industry (and all others that rely on hydrogen) that hydrogen and synthetic gases produced using it will always be relatively scarce and expensive from today's perspective.

This means that SSG must do everything in their power to prepare their production sites for the use of renewable gases. As soon as the gases are available, they must also use them.

SSG also needs to make sure that their processes now already need as little natural gas as possible, and in future even fewer synthetic gases. At the same time, it is important to establish an active presence in the political and public spheres. What are needed are the general conditions and economic stimuli to make these gases available in the necessary quantities.

In addition to availability as well as the conditions in terms of prices and the political requirements, use of hydrogen in the steel industry still presents a number of other technical challenges:

1. In the transition phase, H2 is mixed with natural gas. This is no problem up to a volume ratio of 10% - 15%. Anything more requires different combustion technologies.
2. H2 burns hotter and with a shorter flame so that "hot spots" occur in places which has an impact on the refractory material of the furnace lining and affects the required burner positioning.
3. Water vapor is produced which is not wet steam, but which affects the furnace atmosphere. It prevents hydrogen absorption in the metal and thus hydrogen-induced brittleness in steel.

Scope 2: Green power instead of embodied energy

Further potential for reducing the amount of CO2 on the electric arc furnace route lies in the use of declared green energy. This considerably reduces the footprint even more. In the Swiss Steel Group plant in Emmenbrücke, Switzerland, this step has already been taken. The plant only uses electricity supplied by Swiss hydroelectric power stations. The site's power consumption is equivalent to that of a Swiss city with a population of 62,000.

However, may be imminent here, too which demand a certain amount of attention regarding the political situation – particularly in Switzerland. As of 2025, 70% of the transmission capacity of the grid in the EU is reserved for power trading within the EU. If no agreement with the EU can be put into place by then, Switzerland is at risk of a power shortage triggered not by a lack of electricity, but by a lack of transport capacity. This power shortage would hit the big consumers first – and thus also the Swiss location of the Swiss Steel Group. Because even though the production sites in Switzerland exclusively source local green electricity, the lack of coordination with Europe and above all the lack of imported electricity can cause the grid to become instable. Thus, also regarding electricity, decarbonization must go hand-in-

hand with political engagement that ensures that industries that take the fight against climate change seriously are not put at a disadvantage.

Scope 3: High-alloyed scrap instead of alloying metals

The greatest and by far most effective means of reducing the carbon footprint is switching from pure primary alloys such as ferrochrome, ferronickel, ferromanganese, or ferromolybdenum to high-alloyed scrap in the production of high-alloyed and stainless steel. The percentage of alloying surcharges specifically in high-performance steel is at times over 30%, and their procurement is energy and CO2-intensive. They also in part come from countries that are politically instable or under international sanction, particularly the important auxiliaries, specifically nickel and chromium. Russia produces around one fourth of the nickel used worldwide and supplies 53% of the nickel processed in Germany.

That's why it is so important in the future both for ecological as well as political reasons to rely more on quality scrap for alloying instead of pure metals. To be able to manufacture high grade steel using high-alloyed scrap, however, new metallurgical developments are needed in which above all the metallurgical lab of the Swiss Steel Group company Ugitech in France has made a mark. One of these breakthrough improvements is the project Ugi'Ring, which at Ugitech is promoted together with regional partners. Its aim is to produce primary alloys from waste products such as batteries, catalytic converters, and similar products to become independent of suppliers of these elements from producing countries that are unstable politically. Ugi'Ring will be the first installation of its kind worldwide and represents the future of steel production that makes the recycling of alloying elements such as old batteries, catalytic converters, galvanic sludges, or filter ash from flue gas scrubbers possible. The facility will be entirely independent of primary alloying elements obtained from extracted raw materials. Ugi'Ring is part of a French national policy aimed at making the country independent of deliveries of these primary alloys and has received 10 million Euros in public funding.

Guaranteeing consistently high quality in the steel melt with scrap is much more difficult than if a pure material were used. A pure alloying element will have to continue to be used for fine adjustment so that assured access to these elements is imperative to produce stainless grades.

Recognize, act, inspire

It is important to recognize in all these measures that action cannot be taken without knowledge. It is common knowledge that steel has a large carbon footprint. Green Steel can be based on internally certified energy management systems and is systematically supplemented by very accurate internal measurements and, where not already in place, detailed data collection on which the thrust of the measures is oriented. Green Steel and the reduction of greenhouse gas emissions are thus primarily also a question of data acquisition and processing, ultimately a "big data project". The data and emission values of Scope 1, Scope 2 and Scope 3 must be recorded properly and will be passed on to customers by the Swiss Steel Group. This puts them in a position to determine the climate footprint of their own products exactly. Since data of this kind is requested ever more frequently and may even been mandated in future, the corresponding databases could also prove to be a competitive advantage for SSG.

The collection and transferring of data and acting on it follow the principle of "recognize, act, inspire". In this context, it is important not to limit oneself intellectually. The research projects for scrap management at the Swiss Steel Group now already go far beyond the actual scrap. In strategic scrap procurement,

care is taken to purchase scrap in such a way that transport routes are kept as short as necessary, and as little scrap as possible is transported by road. These issues are actually only partially related to the core business of the Swiss Steel Group. Just a few years ago, anything remotely attached to this was outsourced, delegated to the cheapest subcontractor, and, in part, made a cost center. These days that is no longer possible. Because the emissions of logistics are also decisive for the carbon footprint of steel, and those who don't know anything about it also can't influence anything and may lose customers to the competition.

Green Steel as a research and technology platform

Close cooperation with scrap dealers and the effort that goes into scrap logistics is making the electric furnace steel industry with its scrap recycling into one of the forerunners of the cyclic economy. Where others are just beginning to differentiate between "waste" and "possible recyclable material", the steel industry is already separating scrap as a recyclable material into dozens of categories with different prices. What's happening here is an example for other industries whether in the recycling of building materials or plastics. Swiss Steel Group is aware of their pioneering role and continues to build on it.

In the world of recycling, the generally accepted principle is that there is no true recycling, but only downcycling. This means that only materials of lesser quality than the original material can be made from recycled materials. The scenario for low alloy steels has been different in the steel industry for quite some time. Thanks to the new Ugi'Ring process developed by Swiss Steel Group it is now possible to reclaim alloying elements such as chromium, nickel or molybdenum from highly alloyed steels with reduced energy input. This means that the new products are of higher quality than the original scrap – and recycling has actually become upcycling.

With all their knowledge of the cyclic economy, recycling and upcycling, the steel industry must develop a new self-awareness as a pioneer of a green economy. Green Steel is becoming a research and technology platform. Just as steel was the pioneer of the industrial revolution, it must now also take on the same role in the green revolution. Both for the climate as well as for the reputation of companies and industry, it is important to pursue a creative, progressive policy on the climate instead of holding onto a reactive, reluctant and reticent attitude.

This is why active, serious and effective measures to protect the climate in the long term are decisive for the Swiss Steel Group both within and outside of our own business segment which can then also be followed by corresponding public relations work in a second step.

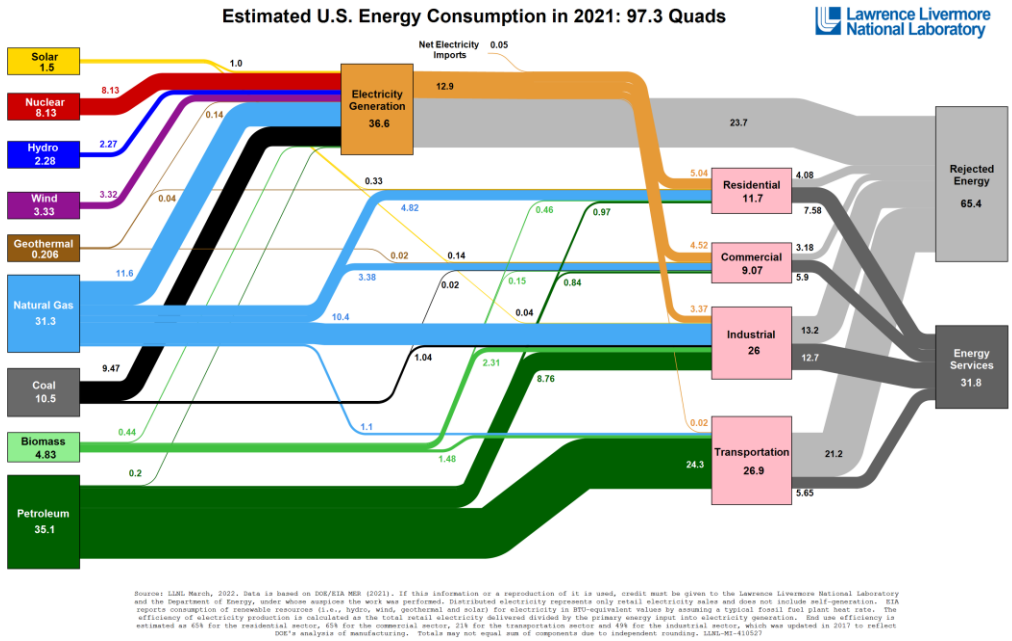
Worthless waste heat as a resource and costly traction energy

Green Steel as a research and technology platform comes in many shapes and sizes. The big data projects already launched and running for scrap logistics in cooperation with universities and research institutions are just one of them.

Waste heat is also an important area of research. High-temperature waste heat, for instance, can be stored in thermal batteries. These thermal-energy storage batteries consist of heat exchangers cast in special concrete or phase change materials (PCMs) – usually molten salts capable of absorbing and releasing heat at very high temperatures. Thanks to these thermal-storage batteries waste heat can not only be stored but also easily transported and used to generate electricity, process heat, cold or steam.

Entirely new or long-forgotten applications are also conceivable for waste heat. When waste heat is converted into electricity by means of a steam process using conventional heat-recovery steam generators, the value of the waste heat is € 10/MWh at a feed-in tariff of € 30/MWh electricity. This is so low that recovery measures (heat recovery steam generator, steam turbine, generator, electrical installations, control devices) rarely turn out to be profitable. Which is why this avenue is almost never pursued.

However, if waste heat is used via the same steam process not to generate electricity, but instead to produce traction and thus replace diesel fuel, the value of waste heat amounts to € 186/MWh given current fuel prices. Accordingly, Green Steel is ideal for test and development projects in new traction systems in rail and road transport as well as for in-plant logistics. It is possible, for example, to run locomotives, scrap ferries and sludge transporters using waste heat from the steel mill. The principle is based on the so-called battery electric multiple unit, a steam locomotive powered by onboard batteries without steam generation or the need for combustible materials. Steam is produced by a conventional heat recovery steam generator and then “filled up”. The energy storage medium is hot water under high pressure. Charging takes around 20 minutes and is generally sufficient for an eight-hour shift.



Almost all questions related to the turnaround in energy and climate policy revolve around the left section of the diagram above representing energy sources and energy carriers. The right section, however, is much more important. It reveals that two thirds of the energy consumed in the US (the situation is similar in other countries) is lost as waste heat. A new perspective on waste heat, its organization and use are thus much more important for decarbonization than a couple of additional solar panels. The steel industry as a major and very centralized producer of waste heat is called upon to step up to this challenge. Green Steel means not shying away from these questions, but searching for answers.

Green Steel as a signal for other industries

In addition to the research and technology platform, Green Steel will thus send a signal to the wider economy. It starts with detailed documentation and continuous reduction of our footprint. The next step is to reveal the advantages of steel over other materials to other industries. Steel in the automotive industry often has a smaller CO2 footprint than carbon fiber constructions and lower costs and a smaller CO2 footprint than aluminium. It is also easier to recycle than composite materials.

The Bainidur steels must also be mentioned in this context. They have a bainitic structure ex works. This means no further heat treatment for the customer and considerable savings in the consumption of natural gas and the corresponding emissions.

Not just an eco-label for steel, but an invitation to think and cooperate

The harder it's looked for, the more Green Steel signals can be found that can be put to use both by SSG as well as their customers. With their enormous worksites, halls and rail networks, with their logistics and energy infrastructures, the SSG plants are an ideal launch platform for green technologies that have an impact internally and externally.

Green Steel refers on the one hand precisely to the CO2 content of SSG products. Green Steel, however, will be much more in future than just an eco-label for steel. Green Steel defines the reduction path to be taken by the Swiss Steel Group to lower the impact on the climate. It is also an invitation to business partners, researchers, authorities and external organizations to decarbonize the economy together. Because if decarbonization doesn't work in the steel industry, it won't work anywhere.

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