STIL

THE SALZGITTER AG MAGAZINE

Hydrogen

The element and its importance for steelmaking and the dawn of a sustainable future

Bernhard Kleinermann
Head of Corporate Communications

Welcome to our special edition!

It is often the little things that have the ability to change the world. Hydrogen, the smallest of all the elements, is one of these: It is thanks to H_2 that Saturn rockets were launched from Cape Canaveral, and today it is powering local passenger trains in Germany.

Hydrogen has significant future potential in the field of mobility, and could well play an important role in industry as well. At our steelworks in Salzgitter, for example, where in the near future it will help us to produce steel with less CO_2.

The following pages will explain how this is possible thanks to our SALCOS® concept, as well as outlining the pioneering projects that have already been initiated by the Salzgitter Group, and how we are already using hydrogen now.

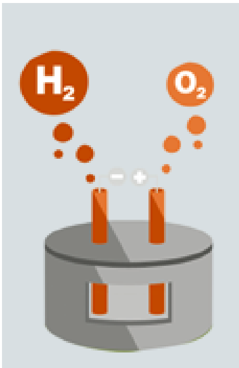
We hope you enjoy reading our magazine!

Cordially,

Cover: iStock© smirkdingo; Photos: Carsten Brand, Gunnar Garms

EU Commissioner Günther Oettinger (2nd from left) was keen to learn more about the SALCOS project **Page 10**

STIL Cover story



GrInHy 2.0: generating hydrogen through high-temperature electrolysis **Page 12**

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Salzgitter AG,
Eisenhüttenstr. 99, 38239 Salzgitter
Telephone: 05341 / 21-01
www.salzgitter-ag.com

RESPONSIBILITY LIES WITH
Bernhard Kleinermann
(Head of Corporate Communications)

COORDINATION
Olaf Reinecke

READER SERVICE
Michaela Kruffke,
Telephone: 0 53 41 / 21-57 01
E-Mail: stil@salzgitter-ag.de

REALIZATION
Schau Verlag GmbH,
Hochallee 77, 20149 Hamburg
Telephone: 040 / 32 87 27-0
info.stil@schauverlag.de

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The H_2ope for the future

Mastering the future with wind and hydrogen

Water and wind are becoming increasingly important resources, as hydrogen derived from renewable energy sources can enable sustainable industrial production – and low-CO_2 steelmaking. Professor Heinz Jörg Fuhrmann, Salzgitter AG Executive Board Chairman, is confident: “In future, hydrogen will be of major importance for mobility, energy generation and storage and many other industrial processes.” Salzgitter AG has developed solutions and launched projects that are exemplary for the sector.

Photo: adobestock© Michael Halberg

And then it went boom! The detonating gas experiment at school

Photo: Infrequent_Flyer / Alamy Stock Photo

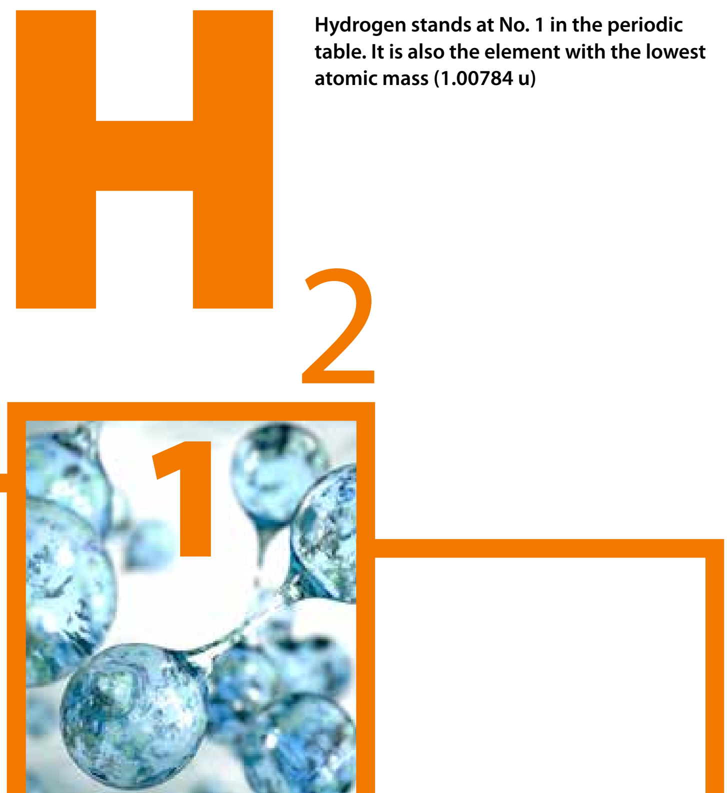
Small element, great hopes

Hydrogen is regarded as the key to sustainable energy management. Researchers and industrial companies are working intensively to develop the potential of this element and render it usable

Hydrogen? For many of us, the very word brings back memories of the loudest moment in our school days – the detonating gas experiment in the chemistry lab. And what did we as students learn from that? We learned that a mixture of hydrogen and oxygen in the right proportions can be highly explosive, and the product of that explosion is water!

That‘s enough to set students dreaming: What if we filled our tanks with hydrogen, mixed it with oxygen and used it to power a combustion engine or a furnace – and the product emitted through the chimney or exhaust pipe were water?

But it is not quite that simple: The element may be the commonest in the universe and available everywhere, given that it is contained in most organic compounds, and especially water. But it cannot be plucked from trees, nor dug from the ground, for hydrogen is virtually never to be found in its pure form. It



Hydrogen stands at No. 1 in the periodic table. It is also the element with the lowest atomic mass (1.00784 u)

11,300 m^3

That was the amount of hydrogen that filled the first Zeppelin Z1

must be unlocked from chemical compounds.

Hydrogen molecules are comprised of two atoms, hence the spelling “H2” (hydrogenium, Greek, meaning “producer of water”). The molecules are extremely light and penetrate through many materials – in extreme cases even steel. For this reason, even the earth’s atmosphere cannot stop hydrogen from steadily escaping into space. Geologists believe that since its creation, the earth has already lost a quarter of its sea water in this way. This is due to the fact that bacteria and solar radiation are permanently splitting water into its component parts, oxygen and hydrogen, and releasing the colorless and odorless gas.

74

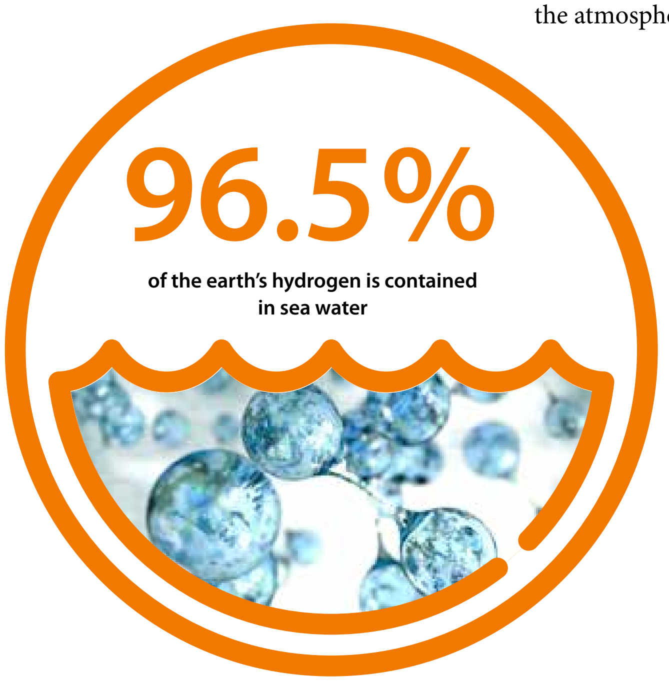
The number of hydrogen filling stations currently in Germany (as of September 5, 2019)

How hydrogen is captured

There are various processes that can be applied if we wish to harness hydrogen. The commonest methods are firstly electrolysis, in which electricity is used to split water into oxygen and hydrogen, and secondly reformation, in which the element is released from hydrocarbon compounds with the aid of heat. Nowadays, the process is mainly applied to natural gas, but gasoline, methanol, biogas and biomass can also yield hydrogen. While other methods are being trialed or researched, they are not yet ready for practical use. For example, some universities are working on solar cells which employ solar radiation to split water – in emulation of the technical processes in the atmosphere.

–259 °C

The very low temperature at which hydrogen liquefies (by comparison, oxygen liquefies at –183 °C)



96.5%

of the earth’s hydrogen is contained in sea water

Photos: shutterstock, falticon

160 Mio.

balloons, that's how many could be filled with the hydrogen currently consumed each month at the Salzgitter steelworks. That would be 62 balloons per second

Consequently, some refined technologies are required to obtain a supply of hydrogen. The element itself is regarded as a great hope for our future energy sector, in which the hydrogen model is seen as a highly promising blueprint for a modern, sustainable industry. There are two reasons for this. On the one hand, hydrogen is unproblematic as a fuel, and on the other, it is a superb source of energy.

Hydrogen is regarded as unproblematic due to its – at least theoretically – high availability and its environmental sustainability. When combusted, apart from a non-critical quantity of oxides of nitrogen, it emits no environmentally hazardous exhaust; only water. This is why Salzgitter AG as a pioneer - meanwhile followed by other steel producers - is looking at hydrogen to replace carbon in the production of pig iron in order to significantly reduce CO_2 emissions (more on this from Page 10 onwards).

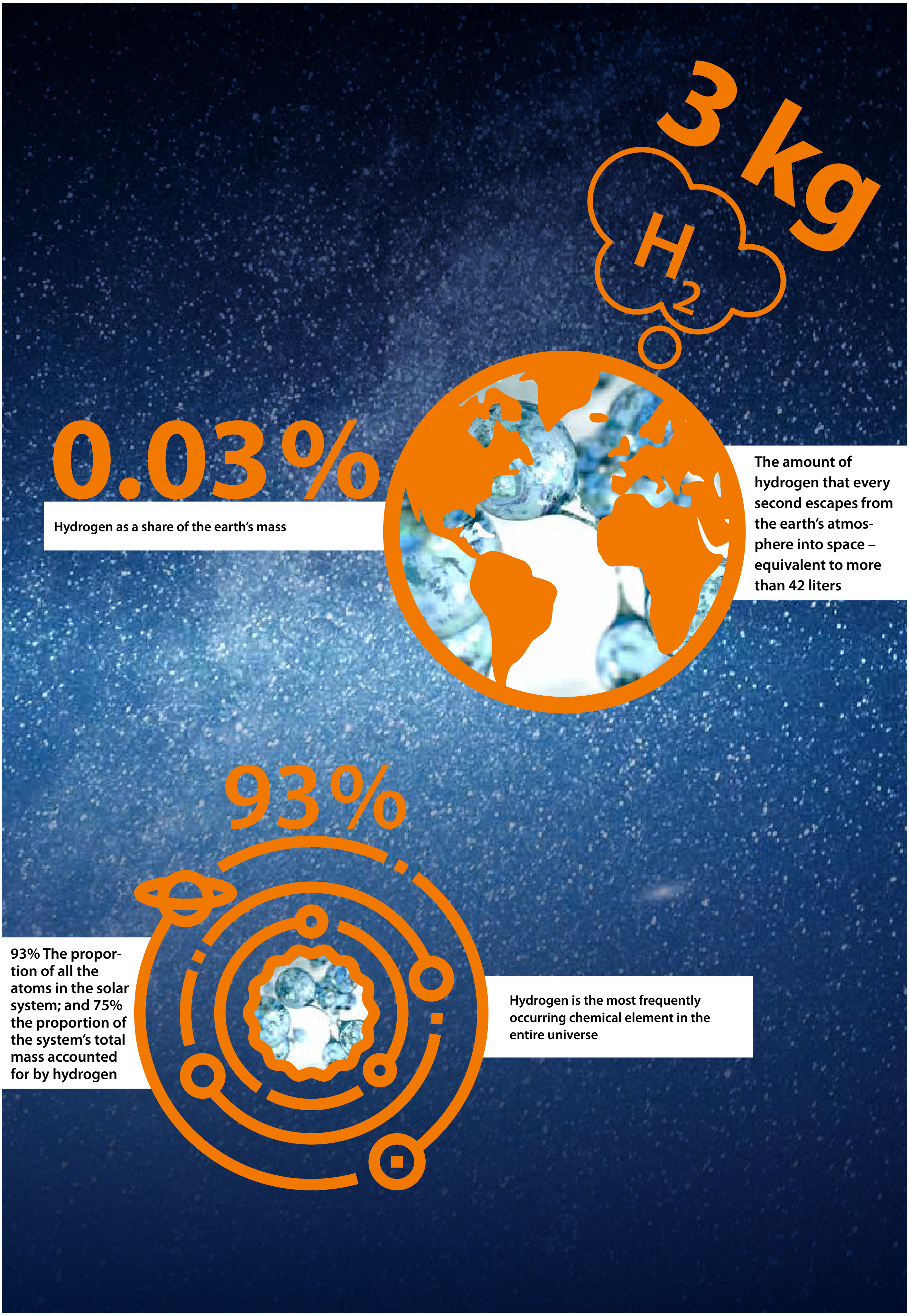
The element is well suited thanks to its very high calorific value. It makes sense to produce the hydrogen on location, where it is needed, as Salzgitter Flachstahl GmbH plans to do at its steelworks. With no transport required, a greater share of the energy employed is retained, while more effective electrolysis also improves the energy efficiency. Salzgitter AG is testing this approach together with its partners in the GrInHy2.0 project (see Page 10).

Projects like this demonstrate that with a large number of technical solutions being trialed and some prominent partners intensively engaged in generating and using this element, hydrogen is a source of great hope for a climateneutral energy sector and industrial processes – and therefore also for sustainable steel production.

that is how much a liter of hydrogen weighs, barely 7% of the weight of air. A cubic meter of liquid hydrogen weighs only 70 kg – just a little heavier than styrofoam

1766
Hydrogen was discovered to be a combustible gas

1784
The element was given its name



3 kg

The amount of hydrogen that every second escapes from the earth's atmosphere into space – equivalent to more than 42 liters

0.03%

Hydrogen as a share of the earth's mass

93%

93% The proportion of all the atoms in the solar system; and 75% the proportion of the system's total mass accounted for by hydrogen

Hydrogen is the most frequently occurring chemical element in the entire universe

The planned location of the seven turbines of Salzgitter Flachstahl GmbH with a total output of 30 MW. Three are to be erected directly on the site of the steelworks, four just outside. The units could go into operation as early as 2020

Photos: SZAG

Into the future with hydrogen

Driving its SALCOS®, WindH2 and GrInHy2.0 projects forward, Salzgitter AG is pioneering low CO_2, water-based steel production

Steelmaking is an energy-intensive business. In terms of the process, there is basically nothing that can be done about that. The blast furnace route – 95% of primary steel production around the world relies on this method – is already running at maximum efficiency. The use of renewable energies and hydrogen instead of coal, however, will soon make sustainable, low-emission steel production a reality.

Where we are today: In Europe, the blast furnace method almost always uses carbon in the form of coke and pulverized coal to reduce iron ore. This process creates carbon dioxide. To ensure that less of it reaches the atmosphere, CO_2 could be stored underground ("Carbon Capture and Storage", CCS) or chemically converted to other substances and thereby recycled ("Carbon Capture and Usage", CCU).

Salzgitter AG was the first steel producer to opt for a more sustainable way from the outset, which is now finding an increasing number of proponents across the industry – the decarbonization of steel production by means of hydrogen and green electricity. Instead of thinking about what to do with the undesirable greenhouse gas CO_2 when it has already been created, the Group wants to intervene directly in the steel production process to generate considerably less CO_2.

The SALCOS® project – a better way

Salzgitter AG has coined the expression "Carbon Direct Avoidance" (CDA) for this approach. The aim, particularly ambitious from an economic perspective, is to harness alternative metallurgical processes which largely avoid the creation of CO_2. Hydrogen plays the key role here. It is to replace coke and coal in extracting iron from iron ore which would drastically reduce CO_2 emissions. The hydrogen in turn is to be produced in a climate-neutral process by means of electrolysis drawing on electricity from renewable energy.

The SALCOS® (SAlzgitter Low CO_2 Steelmaking) project describes this complex transformation process for the integrated steelworks in Salzgitter in detail; here the Group is working intensively with partners from industry and research, such as Tenova and the Fraunhofer Gesellschaft, for example.

The core of this technical approach to avoid CO_2 and therefore also at the heart of the SALCOS® project, lies in the Direct Reduction Process (DRP) in which any ratio of hydrogen and natural gas can be used as the reducing agent. The process is basically not new and is already employed on a major scale, mostly outside Europe, wherever natural gas is available at attractive prices. SALCOS® aims to make increasing use of hydrogen that has been created in a climate-neutral process. However, to date, no such flexible operation of direct reduction systems with natural gas and hydrogen has been achieved on an industrial scale anywhere in the world. Nevertheless, the present findings from large-scale trials suggest that no fundamental difficulties are to be expected.

Hydrogen "Made in Salzgitter"

This poses the question as to where the hydrogen is to come from. Without a doubt, it will have to be produced in a climate-neutral process with regenerative energy to avoid simply shifting the emissions saved in the production of steel to another part of the process. Another Group project now enters the picture, as exciting as it is promising: "Wind Hydrogen Salzgitter". The project is a further concrete step towards a hydrogen-based steel industry and represents an investment volume of € 50 million.

On October 30, 2018, Salzgitter Flachstahl GmbH, industrial gas supplier Linde AG and Avacon Natur GmbH, a company specializing in the construction and operation of gas and electricity grids, signed a contract for the "Wind Hydrogen Salzgitter" project, also referred to as WindH2. Its aim is to produce hydrogen in Salzgitter by means of PEM electrolysis using electricity generated by wind power. The plan is to set up seven turbines in Salzgitter on land owned by the Group. "The turbines are to go into operation in 2020", as Ralph Schaper, Head of Energy Management at Salzgitter Flachstahl, stated.

At the heart of the "Wind Hydrogen Salzgitter" project is the construction and operation of a PEM electrolysis plan with a hydrogen production capacity of around 400 norm cubic meters per hour (Nm^3/h). PEM stands for "Proton Exchange Membrane". This is a technically proven method of making protons pass through a membrane by applying a voltage. In the process, water splits into its constituent parts of hydrogen and oxygen. "The membranes are relatively low maintenance and have a service life of seven to ten years", says Ralph Schaper.

The PEM electrolysis plant will be set up centrally on the factory site. The pure water required for the process is produced in the Group's own plant which processes the service water from the steelworks. Besides the hydrogen, it may also be possible to use the oxygen also produced by electrolysis for operational purposes.

Salzgitter already has a hydrogen infrastructure to supply the hood-type annealing furnace and the hot dip galvanizing line (see page 16).

"We view the "Wind Hydrogen Salzgitter" project as a significant building block on our way to more climate-friendly steel production."

Prof. Dr.-Ing. Heinz Jörg Fuhrmann, Chairman of the Board of Salzgitter AG

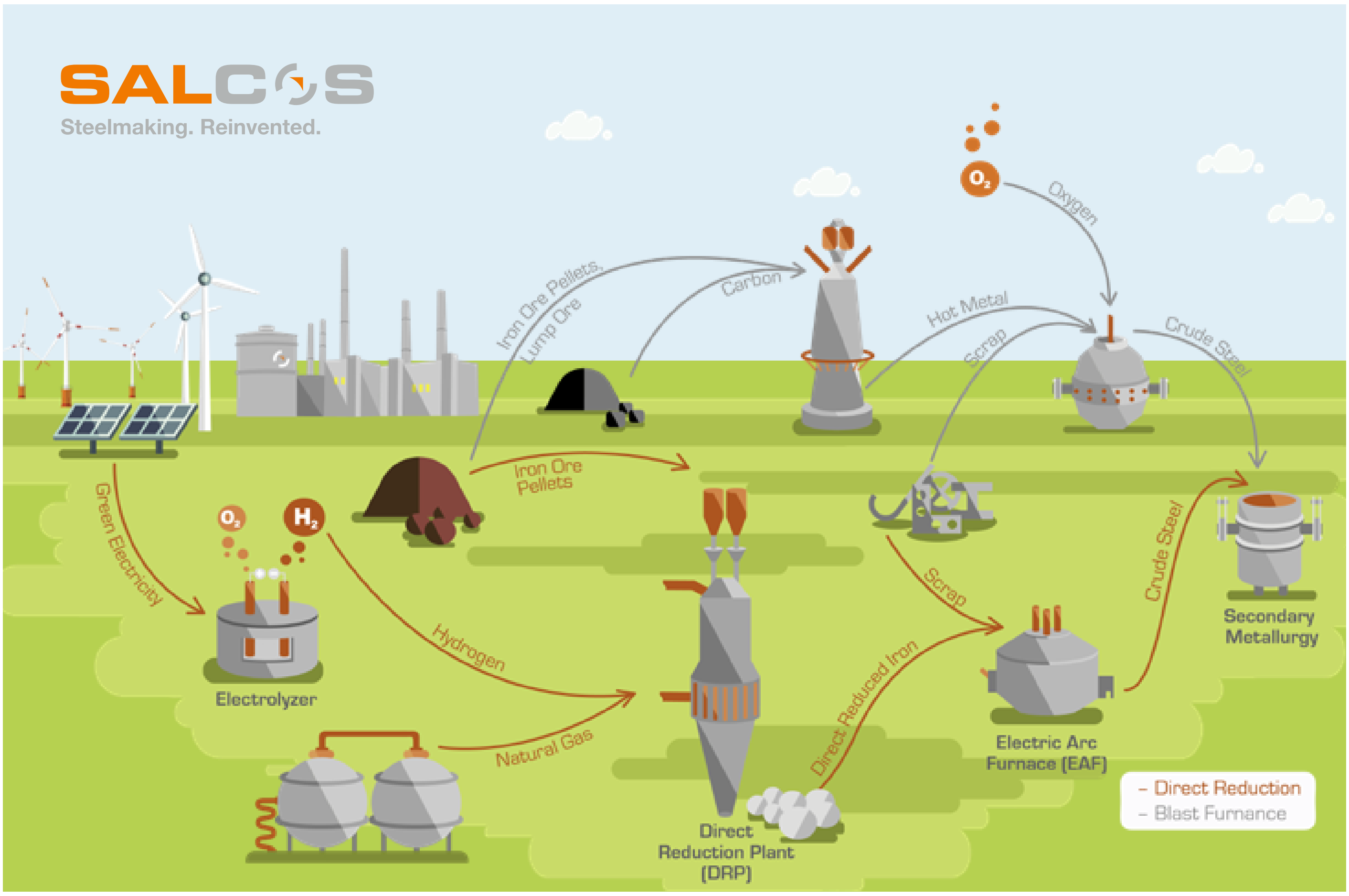
Photos: SZAG, Carsten Brand

Salzgitter AG and Tenova sign Memorandum of Understanding (from the left): Dr. Volker Hille, Corporate Technology Salzgitter AG; Dr. Markus Dorndorf, Product Manager Melt Shops Tenova; Ulrich Grethe, Member of the Group Management Board of Salzgitter AG; Paolo Argenta, Executive Vice-President Upstream Tenova; Christian Schrade, Managing Director of Tenova Metals Deutschland GmbH; Dr. Alexander Redenius, Head of Department at Salzgitter Mannesmann Forschung

Current legislation requires electricity from wind turbines to be fed into the public grid. Responsibility for running the turbines and connecting them lies with project partner Avacon. Linde, on the other hand, is mainly involved in the WindH2 project to ensure reliability in the supply of hydrogen, and it is running a hydrogen storage facility on the site of Salzgitter Flachstahl. All three partners are committed to using WindH2 to gain know-how in the climate-friendly production of hydrogen with connection to an integrated steelworks. The first hydrogen from PEM electrolysis is to be produced on site in 2020.

Project of the future – GrInHy2.0

This is already happening today on a small scale. While WindH2 is relying on the imminent production of hydrogen drawing on a proven electrolysis technology, the "Green Industrial Hydrogen" research project (GrinHy, i.e. "Green High") in which Salzgitter AG is involved, is testing the prospects for an alternative electrolysis path. Together with Sunfire GmbH and further partners from five EU countries, Salzgitter AG worked on this successful EU innovation project from March 2016 to February 2019.



In GrlnHy, high-temperature electrolysis (HTE) is employed to produce hydrogen. In contrast to water electrolyzers, HTE uses steam at around 150 °C which is generated by means of waste heat from steel production.

The process represents very promising future technology because by integrating waste heat, it has significantly higher electrical efficiency than alternative electrolysis technologies. The GrlnHy project has shown the feasibility of operating an HTE system in the industrial environment of an integrated steelworks and in the process meeting the necessary hydrogen quality standard over several thousand hours.

A pilot plant went into operation on the site of the steelworks in October 2017. Even before the project was successfully concluded in February 2019, Salzgitter Flachstahl GmbH, Salzgitter Mannesmann Forschung GmbH and Sunfire GmbH launched the follow-on project GrlnHy2.0 with new partners. The two engineering companies Paul Wurth S.A. and Tenova S.p.A. as well as the French research center CEA are now also on board. The total budget for all partners amounts to some € 5.5 million. The project receives support from the Fuel Cell and Hydrogen 2 joint undertaking and the European Commission.

By comparison with its predecessor, GrlnHy2.0 is to achieve even higher efficiency – up from 78% to at least 84% (in relation to the calorific value). It is also planned to increase the power of the electrolysis plant from 150 to 720 kWel (kilowatt electric). With WindH2 and GrInHy2.0, Salzgitter AG is banking on a sensible combination of tried and tested technology and more novel approaches, thereby establishing an important technical foundation for the SALCOS® project - and with it for the hydrogen-based decarbonization of steel production.

Modeling shows that SALCOS® will offer significant savings potential. In the first stage of its development, CO_2 emissions could fall by up to 26% by around the year 2025. By 2050, CO_2 emissions could be reduced by an amount exceeding EU climate targets. If the entire steel production in Salzgitter were to be converted to the new method with direct reduction plants, electrolyzers and electric arc furnaces, a reduction in CO_2 emissions of up to 95% could be achieved.

Salzgitter AG is already taking further specific steps towards the future in order to up the pace of the SALCOS® project. For example, the Group and Tenova signed a Memorandum of Understanding in the course of this year's Hannover Trade Fair. In it, both sides underline their commitment to the partnership in any possible realization of the SALCOS® project.

Tenova, a company belonging to the Techint Group, is a global specialist in innovative, reliable and sustainable solutions in the fields of metals and mining. Tenova is contributing its ENERGIRON-ZR direct reduction technology to SALCOS® which is especially well suited to the flexible operation the company has set its sights on; the technology was jointly developed by Tenova and its partner Danieli.

"SALCOS® also represents a way of securing the viability of Salzgitter as a steel location and the jobs there"

Ulrich Grethe, Member of the Group Management Board of Salzgitter AG

The GrlnHy plant on the site of Salzgitter Flachstahl GmbH. By mid-2020, the follow-on electrolysis plant is to produce 200 Nm3 per hour, as well as to run for at least 13,000 hours during the four-year project and produce 100 t of hydrogen in this time

Experts in the Group have no doubt that Salzgitter has embarked on a path that is both feasible and sustainable with its ground-breaking strategy of CO_2 avoidance. “Technically, it can all be done and the technologies needed are basically available”, says Dr. Alexander Redenius, Head of the Resource Efficiency and R&D Coordination Department at Salzgitter Mannesmann Forschung GmbH. Management sees itself vindicated by the increasingly discernible readiness of other steelmakers to pursue a similar direction. “For us, this is proof that we took the right path from the very outset”, as Dr. Volker Hille emphasized.

The most important challenge and prerequisite for the actual realization of SALCOS® remains the creation of the necessary regulatory conditions for cost-effective, H_2-based steel production and conversion of the steelworks without compromising on product quality or plant availability.

The financial hurdles here, however, are higher than any technical barriers. This is due to the fact that from a business perspective, it currently makes no sense for a European steel producer to invest in direct reduction technology with electric steel production. The cost of natural gas, hydrogen and electricity including ancillary costs is simply too high by comparison with the coal used today. Setting up the new production technology on the major scale required is only justified, however, if steel can still be produced at competitive prices.

For this reason, the underlying conditions for the domestic steel industry will have to change – also with a view to climate protection. This also includes subsidizing the necessary investment measures. “SALCOS® cannot be realized without considerable public start-up finance – and we are stating this quite openly. Incidentally, such a request is nothing out of the ordinary; other successful companies have received public investment support for major pioneering projects”, notes Prof. Dr.-Ing. Heinz Jörg Fuhrmann, CEO of Salzgitter AG.

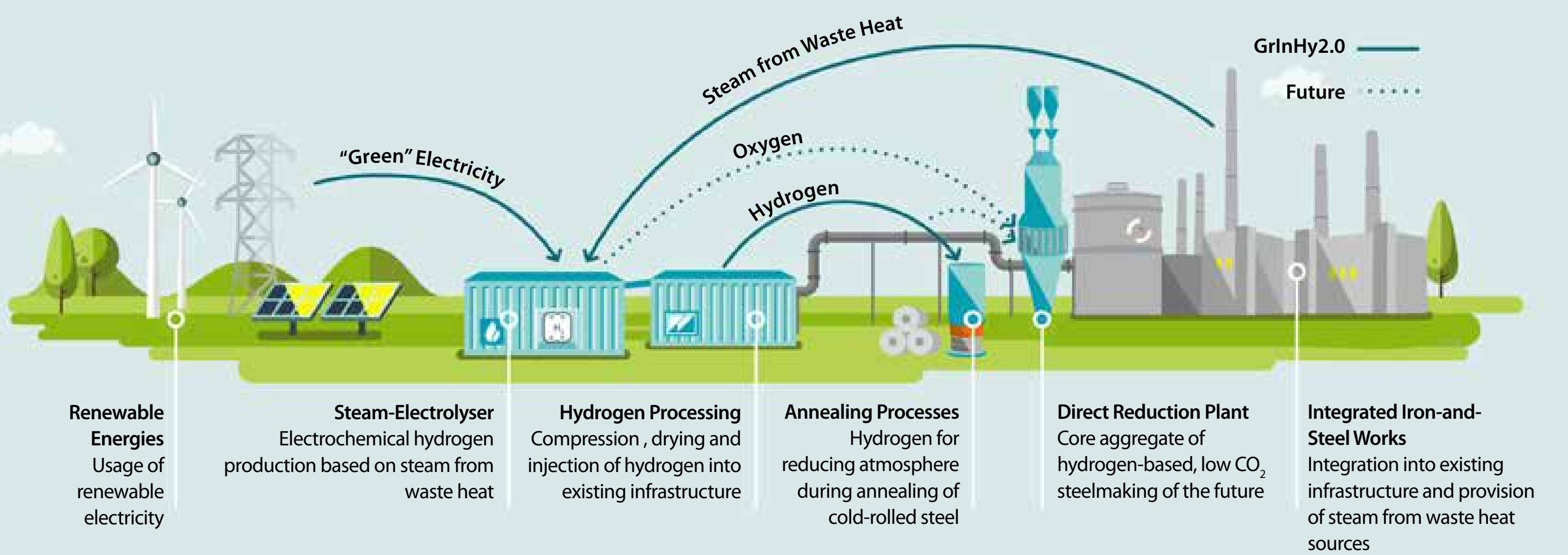
Photo: Tenova

A tower like this could also stand in Salzgitter: ENERGIRON-ZR direct reduction plant of Salzgitter partner Tenova in Egypt

“The SALCOS® concept could become a crucial milestone for our industry”

Paolo Argenta, Executive Vice-President Upstream Tenova

Climate-friendly steelworks



The future, made by "Mannesmann H2ready"

Mannesmann Line Pipe offers products and solutions to support the development of a future hydrogen network infrastructure – including special hydrogen transportation pipes

Photos: Mannesmann Line Pipe

The special pipes significantly exceed the minimum requirements for hydrogen-compatible pipes

Hydrogen will in future play a significant role as an energy source. This will not only require storage tanks, but also pipework for short-distance transportation, as well as pipelines. The material employed to manufacture the pipes, however, must meet stringent requirements. Hydrogen atoms are extremely small and are able to penetrate many materials - including even metals. Nevertheless, steel is the perfect solution and is clearly superior both technically and economically to other materials such as plastics. Transporting hydrogen via pipelines requires the hydrogen to be kept under high pressure, so that its energy density is equal to that of an equivalent volume of natural gas.

With the advent of its special "Mannesmann H2ready" pipes, Mannesmann Line Pipe is now offering products suitable for the transportation of hydrogen – here and now. "They are notable for their alloy composition, their very smooth interior surface, and for the welding process we have in place," explained Konrad Thannbichler, Sales Manager at Mannesmann Line Pipe GmbH. The proportions of phosphorus and sulfur, for example, are well below the guidelines recommended by the European Industrial Gases Association (EIGA). This alloy composition minimizes the potential for hydrogen to attack the material, and thereby reduces the susceptibility of the pipes to corrosion.

The carbon content, too, is significantly below EIGA stipulations, and this in turn optimizes the weldability of the pipe material. Mannesmann Line Pipe relies on the high frequency induction (HFI) process, an electric resistance welding technique, to weld the longitudinal pipe seams. This method involves using high-frequency induction current to heat the pipe edges to welding temperature.

In order to enhance the economic efficiency of these pipes, Mannesmann Line Pipe also employs material of higher strength which in turn means that wall thickness can be reduced, thereby lowering material costs. For a long time, only lower-strength steel pipes up to grade API 5L X52 (L360) were considered suitable for hydrogen. With the support of researchers at Salzgitter Mannesmann Forschung GmbH, however, Mannesmann Line Pipe has meanwhile also demonstrated the suitability of HFI-welded steel pipes in grades up to X70 (L485): None of the investigations have revealed any sign of increased impairment - either of the material strength or of the HFI weld seam due to hydrogen.

In actual practice, pressures up to 350 bar can be encountered when transporting or storing hydrogen in pipe storage facilities or tanker trucks. Even these extremes can be covered by the thick-walled, high-strength products offered by Mannesmann Line Pipe. By comparison, existing hydrogen pipelines in North Rhine-Westphalia and in the central German Leuna-Bitterfeld-Wolfen industrial complex operate at 20 bar, while a pipeline in existence since 1969 and extending for 232 km in Texas (USA) works at 58 bar. Konrad Thannbichler is quite sure: "The special 'Mannesmann H2ready' pipes offer an outstanding solution for the upcoming development of a hydrogen network infrastructure."

"Mannesmann H2ready": The product name for special pipes from Mannesmann Line Pipe that are suitable for carrying hydrogen. For more information visit www.mannesmann-innovations.com

Better steel thanks to hydrogen

Salzgitter Flachstahl has been relying on hydrogen in its annealing shop and hot dip galvanizing lines for decades for the precision adjustment of product properties

Photos: Carsten Brand

Operations Assistant Tobias Langermann (l.) and Operations Manager Dr. Jürgen Spehr between the annealing places in the bell annealing shop

What we humans need to breathe is not always good for steel: Air and oxygen may impair the quality in the annealing shop and the two hot dip galvanizing lines due to oxidization, which is why hydrogen is used as a shielding gas in these production stages.

Hydrogen is delivered by truck from Leuna in a highly compressed and liquid form and stored in Salzgitter on the steelworks' premises in liquid gas tanks where, after transport, it expands to a tenfold volume again. Every month 400,000 m^3 of the gas flows through the plant's own supply pipes to the annealing shop and the hot dip galvanizing lines 1 and 2. This is enough gas to fill 160 million balloons a month and release 62 of them every second of the day into the sky.

Each of the two hot dip galvanizing lines consumes 100,000 m^3 a month of the hydrogen currently used in Salzgitter, while the annealing shop takes the other half, namely 200,000 m^3. Almost 100 % pure hydrogen is deployed there today. Given this high saturation, the gas initially has to be compressed by up to 10 bar and then dried in a pressure swing absorption unit. By contrast, nitrogen in the hot dip galvanizing lines has hydrogen added to it in the following quantities: 20 % in Line 1 and 5 % in Line 2.

The annealing process gives all sheet products and and galvanized sheet the desired quality. Heating, maintaining the temperature and cooling changes the structure of the steel – the term "micro structure" is also used –, which serves to improve its properties, including yield strength, tensile strength and elongation.

Steel goes on an annealing journey

Precisely 81 annealing places are available for this procedure in the bell annealing shop. Three to five coils are stacked up on eight to twelve of these assembly bases per shift. Together they weigh a maximum of 100 tons and can be as high as 5 m. It is this point that the "annealing journey", as it is called by the experts, begins. This process takes between 50 and 80 hours.

At the start of the journey, an overhead crane lifts a cover made of stainless steel over the stack of coils. Nitrogen then floods the inner chamber and washes away any residue of oxygen. In the next step, a larger heating bell is placed over the cover. Twelve natural gas burners then ignite to heat the space between the outer and inner covers. At the same time, hydrogen floods the chamber and displaces the nitrogen. As hydrogen molecules are very small, they penetrate the ring-shaped coils between the wound steel sheets.

Hydrogen fulfills two tasks in the inner cover, which Dr. Jürgen Spehr, operations manager of the annealing shop and skinpass mill, explains as follows: "Firstly, it is an excellent conductor of heat and therefore effectively conveys the heat from the outer cover to the stacked coils. Secondly, it removes the rolling oil still sticking to the material. The oil burns at 200 to 500° C – the temperature in the annealing bell is between 670 and 720° C."

The volume in the chamber of the inner cover is 30 m^3. As hydrogen is constantly flushed through in order to burn any residue oil, each annealing process requires around 290 m^3 of the gas. The hydrogen siphoned off is burned and also heats the overall process. The heat is maintained for 6 to 35 hours, after which the heating bell is replaced by a cooling bell and the inside is cooled by air and water. After around 18 hours, the hydrogen is replaced by nitrogen.

Each annealing journey is defined by an "annealing key". These keys define the annealing temperature as well as the heating up, steady state and cooling times, along with the consumption of hydrogen. The parameters vary depending on the steel grade as well as the size and weight of the coils. At present, around 25 different annealing keys have been specified. The process has been applied since the 60s and optimized further since then. While initially, a mixture of gas was deployed with a 5 to 8 % share of hydrogen, 100 % pure hydrogen has only been in use since 1987.

Hydrogen in hot dip galvanizing

After the annealing process, the sheets can be galvanized, representing another process in which hydrogen plays an important role. Salzgitter Flachstahl operates two hot dip galvanizing lines. Hot Dip Galvanizing Line 2 is considered the most complex facility of all in the cold rolling product segment. The line combines several process steps and also takes care of annealing so that no coils from the bell annealing shop are processed here.

Hot Dip Galvanizing Line 2 is a vast, impressive facility soaring to a height of more than 50 meters. All the processes are fully automated and controlled by a handful of employees. In contrast to annealing, the material is uncoiled at the start of the process, threaded and then welded to the end of the previous coil. The outcome is an endless strip that can be recut. The diagram of the entire facility brings to mind an old film projector which takes celluloid strips and transports them via reels and spools up and down and then winds them up again at the end.

Alexander Georgiew, Production Manager Galvanized Steel Sheet, Dr. Frank Barcikowski, Operations Manager Hot Dip Galvanizing Line 2, and Dr. Michael Brühl, Operations Manager Cold-rolled Flat Products (f. l.). Hot Dip Galvanizing Line 2 is shown in the background

In Hot Dip Galvanizing Line 2, the steel strip is pre-cleaned in several upstream stages and then annealed in the furnace at temperatures of 690 to 890° C. Throughput in the furnace takes a maximum of ten minutes. After an initial cooling to 210° C, the running strip is then heated again in the induction furnace to 450° C and then hermetically fed through an enclosed feed channel and dipped in the around 420° C hot zinc bath.

The housing of the feed channel is filled with a mixture of nitrogen and hydrogen. The steel is then exposed to air and oxidizes immediately. As a result, a thin layer of iron oxide forms on the strip that has to be removed before galvanizing. "This is what hydrogen does. It reacts with the oxygen from the iron oxide to form water," says Dr. Frank Barcikowski, operations manager of Hot Dip Galvanizing Line 2, explaining the process. This takes place at a temperature of a minimum 500° C and only until the atmosphere in the feed channel has achieved maximum moisture content. This is why it is regularly replaced – every hour 1,000 m^3 of the gas mixture that consists of 5 % hydrogen is exchanged in Hot Dip Galvanizing Line 2. To avoid any air penetrating the interior due to leakage, overpressure is created in the feed channel. Its outlet is directly positioned in the zinc bath, which means that the steel is no longer exposed to air and cannot oxidize again.

Hydrogen therefore also plays a decisive role at the critical point before actual galvanizing takes place, thus making a major contribution to the quality of the galvanized plate that is important first and foremost for the automotive industry.
A small secondary aspect is particularly forward looking in this process: A small amount of hydrogen generated on the steelworks premises in the GrInHy trial facility (see page 10) is already being used in Hot Dip Galvanizing Line 2.

On land, on water and in the air

Hydrogen promotes climate-neutral mobility as a fuel and energy carrier. Above all, the fuel cell is certainly looking towards a bright future that has already begun

Photo: Dennis Hallinan / Alamy Stock Photo

Massive fire, massive propulsion: at the liftoff of the Saturn V rockets a mixture of kerosene, hydrogen and oxygen is ignited in the first stage. The two other stages were filled only with hydrogen and oxygen

The idea of traveling with hydrogen in the tank is nothing new. It was around almost 60 years ago and took man to the moon: All NASA's Saturn rockets that lifted off between 1961 and 1975 in Cape Canaveral were powered bya mixture of oxygen and hydrogen in at least one of their rocket stages. The space shuttle was also catapulted into space with this detonating gas mixture.

Fuel cells for cars and trucks

Couldn't this mixture also drive any other vehicle? In principle, yes. Cars with hydrogen combustion engines have already been trialed for a very long time – above all BMW and Mazda are experimenting with vehicles of this kind. There are, however, disadvantages: Combustion processes are difficult to control, hydrogen is not a very good lubricant, and the efficiency levels are poor.

This is why another functional principle is considered to have better chances in the future: the fuel cell. In this case, hydrogen is not a fuel but an energy carrier, which means: The fuel cell changes the energy chemically stored in hydrogen into electricity and then drives an electric motor. Fuel-cell powered cars are therefore basically electric vehicles that have a small power plant on board driven by hydrogen instead of a battery.

The technology is also interesting for utility vehicles. Charging the battery of a truck causes uneconomical idling times, and the heavy batteries significantly reduce the payload. Here, hydrogen is a great deal less weighty – even measured against diesel: A 40-ton vehicle only needs 9 to 10 kilos of hydrogen for 100 kilometers.

The technology has already set almost everything in motion: Bicycles, scooters, cars, trucks, buses, ships, submarines and even aircraft will soon be powered by fuel cells. The Antares DLR-H2 developed by the German Aerospace Center (DLR) lifted off in July 2009 as the world's first manned fuel cell aircraft. Therefore the claim: fuel cells can power anything that on land, on water or in the air.

Lower Saxony as a model federal state

Once the first vehicles with fuel cell technology are ready for series production, the technology will become the better alternative for companies maintaining larger vehicle fleets, such as freight forwarders and transport companies. One German federal state in particular is already buying into hydrogen: Lower Saxony. The federal state could become a genuine showcase for hydrogen-based technologies. Environment and energy minister Olaf Lies envisages a long-term strategy for his federal state: “Hydrogen is pretty much inevitable if you think the “Energiewende” through to its logical conclusion. This is why we need a hydrogen strategy as a component that will take us forward and away from coal-fired power generation.”

The strategy is to be implemented in a forward-looking manner, as well as through projects implemented with immediate effect. For instance, Lower Saxony intends to take a 100 MW strong power-to-gas pilot facility into operation that can use green electricity to produce hydrogen and methane gas. Faster progress is being made with a current transport project: Two regional trains have linked up the cities of Bremervörde, Cuxhaven, Bremerhaven and Buxtehude since September 2018. These are the world’s first passenger trains powered by fuel cells, built by Alstom in Salzgitter.

Since being commissioned, these hydrogen locomotives have elicited huge global interest, with inquiries from Austria, Norway, England, Canada, Russia, Indonesia, Japan and the Netherlands. Landesnahverkehrsgesellschaft Niedersachsen (Lower Saxony’s public transit authority) responded to the inquiries with “we are thrilled” – another 14 trains have already been ordered. These trains are to replace the entire fleet of diesel locomotives in Bremervörde by the end of 2021.

The process of transition has already begun on rail – and it is set to continue. The Federal State of Hesse has followed the example of Lower Saxony and will soon be replacing old diesel locomotives by fuel-cell powered trains. Fahma, a subsidiary of passenger transport association Rhein-Main-Verkehrsverbunds (RMV) has now ordered 27 fuel cell trains from Alstom for around €500 million. The new rolling stock will serve regional train lines in the Taunus region and are to be delivered by the next timetable change in 2022 to 2023. This transition will mark the kick-off of series production of fuel cell trains in Salzgitter.

Photo: John Gaffen 2 / Alamy Stock Photo

Is this the vehicle bodywork of the future? A vehicle chassis with hydrogen tanks, fuel cell and electric motor. A hybrid vehicle would have a battery on board as well

Photo: Wikipedia

Antares DLR-H2 is a German development and the world’s first manned aircraft ever to be driven exclusively by fuel cells and electric motor

NordWestBahn’s Coradia iLint fuel cell train in Lower Saxony

Photo: Alstom / Michael Wittwer

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