Hydrogen Makes World Premiere

on Lower Saxony's Regional Railways

Have a Great Trip!

When the two Alstom Coradia iLint pilot vehicles rolled out for testing from Bremervörde back in September 2018, there was a lot of nervous anticipation. Would their fuel-cell-driven vehicle design ever reach market maturity—and if so, how fast? I'm pleased to announce that the first fourteen vehicles of this model passed the test phase with flying colours and are now ready for regular operation on the Cuxhaven to Buxtehude line. This project represents a real step forward and is a perfect example of what it means when we say that transformations are Made in Lower Saxony. The Land of Renewable Energy is laying down a significant marker on the path toward a climate-neutral transportation industry.

I want to express my personal gratitude to our partners at Alstom, a truly unique rolling stock manufacturer with the courage to keep innovating no matter what. A very special thanks also goes to the Lower Saxony Transport Authority (LVNG), Linde, and the EVB, whose tireless dedication meant that the world's first fuel cell trains are going to commence regular service on this line just four short years after trials began.

Stephan Weil,
Minister President of Lower Saxony

As The Innovation State, Lower Saxony is also demonstrating that alternative technologies don't have to compromise performance for us to stay on track toward decarbonisation. The use of hydrogen trains can serve the mobility sector in the territorial state of Lower Saxony as a beacon. Lower Saxony's pioneering achievements prove that it's taken the motto "Hydrogen is the New Diesel" deeply to heart. I am so proud of the Ministry's Department of Transport for picking up the € 85 million bill for these fourteen trains and for working side-by-side with LVNG to make this groundbreaking project come to fruition. An additional € 8.4 million in federal support is also helping to draw attention to the project from far beyond our state lines. By embracing fuel-cell technology, rail is putting its full climate capabilities on display once again.

Dr. Bernd Althusmann, Lower Saxony's Minister of Economic Affairs, Employment, Transport and Digitalisation

Germany has set ambitious climate targets. Our country intends to become climate neutral by 2045. Railway e-mobility will be a pillar of the low-carbon transport systems of the future. In its coalition agreement, the federal government pledged to electrify at least 75 percent of the country's railway system by 2030. Alternative drive technologies can help us get diesel engines off our rails. One thing that makes hydrogen-fuelled trains so attractive is that they are able to cover long distances on catenary-free rail lines. Last year the Federal Ministry for Digital and Transport drafted a new technology-independent directive aimed at accelerating the market ramp-up of innovative propulsion technologies in locations were electrification isn't viable. Public investment of the kind we are seeing in these fuel-cell multiple units in Lower Saxony can be a highly effective tool for incentivising greenhouse gas reduction and for driving rail transport decarbonisation. They are not only pivotal in helping us achieve our overall climate objectives but in safeguarding Germany's long-term technological leadership as well. We are grateful to everyone involved for their ongoing commitment and wish all the passengers travelling aboard LNVG's brand new hydrogen fuel-cell multiple units a safe journey!

Elena Hof, National Innovation Programme for Hydrogen and Fuel Cell Technology team leader and programme director at NOW GmbH

World Premiere Offers Breath of Fresh Air!

A breath of fresh air is blowing through Northern Germany. Together with our partners at Alstom, Linde, and the Rail and Transport Company Elbe-Weser GmbH (EVB), we're proud to be kicking off hydrogen's world premiere! The fourteen trains connecting Cuxhaven, Bremerhaven and Buxtehude are not diesel-powered, but run on hydrogen instead—the wind power generated share of which is steadily increasing. This is the very first passenger rail network in the world on which hydrogen fuel-cell-powered multiple units are in regular operation.

"This is the very first passenger rail network in the world on which hydrogen fuel-cell-powered multiple units are in regular operation."

How did it happen? We at the Lower Saxony Transport Authority (LNVG) are responsible for administrating almost all regional rail transport in the state (SPNV). We administer and underwrite around € 300 million worth of train trips per year. Our vehicle portfolio includes over four hundred locomotives, multiple unit carriages, and rail cars, all of which are leased out to a variety of train operating companies. The competition these operators generate helps us keep the passenger experience great and make sure that taxpayers get the best value for their money.

Competition is something that was sorely lacking when it came to propulsion solutions fit for the future of non-electrified rail lines, however. Germany has been talking about the energy transition for ages. Nevertheless, it seemed to us that no one had ever really started any regional railway projects aimed at finding alternatives to diesel fuel. We at LNVG decided that we needed to get the ball rolling! We were the ones who approached manufacturers about using hydrogen power. Our goal was to create a real alternative to diesel, make it economically competitive, and to use it in daily passenger operations. As a public sector company owned entirely by Lower Saxony, we are immensely proud to have contributed so much to this innovation. The transport industry has taken notice. In 2021, the European Rail Supply Industry Association (UNIFE) presented to us its annual "European Railway Award".

Why is hydrogen such an attractive source of energy in Lower Saxony? Well, we are situated on the North Sea. We have wind in abundance. We also have plenty of salt caverns to ensure intermediate hydrogen storage capacity. Initially, we are using hydrogen from a variety of different sources, including industrial waste. Our project partner Linde, who also built and operates the fuelling station in Bremervörde, is responsible for ensuring that supplies are uninterrupted. Linde is ramping up its hydrogen production on site and is expected to continue increasing the share of wind power it uses for electrolysis. This is a truly game-changing project and we consider every step along the way—starting with procuring trains from Alstom, to their maintenance, to keeping them supplied with energy—as part of a fully integrated and groundbreaking new system.

"We consider every step along the way as part of a fully integrated and groundbreaking new system."

What kind of propulsion solutions do we see in LNVG's future? We've already made the decision not to order any more diesel vehicles. In the second half of the decade, we will have replaced even more of our diesel-powered units. Our plan right now is to supplant them all with hydrogen-powered and electric trainsets. We are currently studying which solution best suits each respective network. I think it's worth underscoring that the most efficient energy usage solution in the long run remains electrification. That's a federal responsibility, however, so we don't really have much say in the matter.

"We've already made the decision not to order any more diesel vehicles. In the second half of the decade, we will have replaced even more of our diesel-powered units."

Bremervörde is just the beginning. During 2018/2019, two Alstom-made pilot trainsets spent eighteen months rolling up and down the EVB railway network without breaking down once. The experience made us confident that our line-produced trains would do the same. Take a deep breath because it's time for the world premiere to begin!

Carmen Schwabl, LNVG Managing Director and Spokesperson

LNVG

Here to Keep the Trains Rolling

Andrea Jäger, EVB,
Train Driver

"I get to be one of the first people in the world to drive one of these trains. That's really special." **Andrea Jäger** has been driving multiple unit trains for EVB since 2015. She has experience operating the diesel-powered LINT, spent time aboard both pre-series trains in 2018, and is now driving the production vehicles provided by LNVG. "Train drivers from other companies come up to us all the time to ask about these hydrogen-fuelled vehicles. That's always exciting!"

What does Jäger tell her curious colleagues? "It's so much more pleasant to put in a shift on a hydrogen train than on a diesel powered one. It's just a more relaxed driving experience. The electric traction motor makes so much less noise, which you really notice once you go home for the night." Overall, passenger feedback has been overwhelmingly positive as well. Jäger even confirms the rumour that the days are over when people spilled their coffee any time the train was set in motion. "The electric traction motor has no transmission so there's no need to shift gears. That's why the train accelerates so fluidly and why the transition to cruising speed is so seamless. There's hardly any jerking at all."

The transition from LINT II driver to LINT X driver was easy. "The instrument panel is pretty much identical," the qualified train driver relates. After a bit of training, refuelling also became a breeze. Jäger is full of praise for the new propulsion systems. "The train accelerates faster because the electric motor produces the power needed for traction directly. It's just a lot more fun to drive."

Alstom's **Stefan Schrank** managed to turn a simple idea into the first hydrogen-powered train in the world. "I'm someone who loves to sit down in front of a blank piece of paper and just start designing," the industrial electrical engineer reveals. Back then, he was the third member of Alstom's product development team. The idea to use the gas was originally prompted by Dr. Jens Sprotte and Rainer Don. Schrank recounts that when the two of them started talking about hydrogen, there was a lot of snickering. "It wasn't until a few days later that everyone began taking their idea seriously."

Alstom began deliberating on whether the alternative it would market to DMUs should be battery or hydrogen-powered as far back as 2012. "The government of Lower Saxony has recognised hydrogen's immense potential for a long time. That was certainly an important factor in our decision making," Schrank explains. Getting the vehicles ready to deliver to LNVG was an ambitious undertaking. Testing had to be conducted under laboratory conditions and the team required two full pre-series trainsets. Schrank: "We set up a special test facility in Tarbes, France, and equipped it with a hydrogen tank, a fuel cell and a motor. We spent six months running exhaustive trials on the system back in 2015/2016. It allowed us to simulate a lot of real train lines from home." The pre-series models made their debut on EVB's tracks in 2018/2019. The pride on Schrank's face when he talks about serial production trains operating on the line is unmistakable. "People used to scoff at the idea. Now it's on the verge of making its world premiere. This is the kind of moment that only comes once in a lifetime."

Stefan Schrank, Alstom,
Coradia iLint Project Director

"I have hydrogen coursing through my veins!" **Alexander Zörner**—Linde's fuelling station project director—likes to joke. He is responsible for making sure the trains never run out of gas. Zörner has spent his whole career focusing on the chemical element symbolised by the letter H. As a courtesy reminder: H is the first tile on the top left-hand side of the periodic table that used to adorn the wall of your chemistry classrooms back in school. "It's fourteen times lighter than air, which is pretty remarkable in its own right."

Zörner is a veteran of the hydrogen fuelling station construction game. Building the first one in the world made exclusively for trains, however, was unique even for him. The Bremervörde fuelling station can provide up to 1.6 tons of hydrogen per day. Your typical motorcar could drive one hundred thousand miles on that. This volume of daily refuelling is completely new to me and to Linde as well." It took a combined team of twenty people from Linde and its partners a year and a half to build the Bremervörde hydrail fuelling station. "The residents of Bremervörde have followed our work closely and the feedback has been very positive." For the time being, Linde will deliver hydrogen to the station by truck. The medium-term objective is to produce it on site in a wind-powered electrolysis plant. Flashback to chemistry class. When an electric charge passes from an anode to a cathode through water it creates hydrogen and oxygen. As Zörner explains, "This is how you make the fuel for trains without emitting any carbon."

Alexander Zörner, Linde,
Hydrogen Applications Project Director

It's hard to not to be drawn directly to the translucent container in Thomas Nawrocki's office housing a 1:87 scale model of a hydrogen fuel cell train. Nawrocki—LNVG's Director of Vehicle Management—is one of the people most responsible for seeing these fourteen models become the world's first hydrogen-powered fleet of multiple unit trains.

"They're my babies," the traffic engineer beams with pride. The branches of this family tree extend all the way back to 2012. That was when LNVG experts began contemplating how they wanted their next generation of vehicles to be powered. "That was a pivotal moment when you consider that rolling stock generally has a lifespan of around thirty years," Nawrocki explains. "We began asking ourselves, if we actually believed that diesel would still be an economically viable option thirty years from now." As far as LNVG was concerned, the answer was clearly no. Nawrocki: "In those days, rolling stock manufacturers only had trains made for overhead lines or diesel on the market. We looked and looked, talked to people all over. Then we found Alstom. They assured us that hydrogen was exactly the solution we were looking for."
The Lower Saxony Transport Authority is wholly owned by the state of Lower Saxony. Many people say that public sector enterprises can't be drivers of innovation or of technological advances. Nawrocki's response? "Of course, we thought long and hard about this decision. But we've never looked back, and neither have our public sector supporters. Hydrogen's enormous potential was clear to see, even then." The project benefited from the fact that LNVG's mission wasn't maximising profits but advancing railway transport in Lower Saxony. That meant we could afford to take a chance on adding these trainsets to our vehicle portfolio. Thomas Nawrocki: "Our function as public transport administrators certainly made the decision to be the first company in world to order hydrogen-powered trains a lot easier. We felt that the time for talking about climate had passed and that the time to act was upon us."

Thomas Nawrocki,
Director of Vehicle Management, LNVG

LNVG

Weltpremiere
Wasserstoff

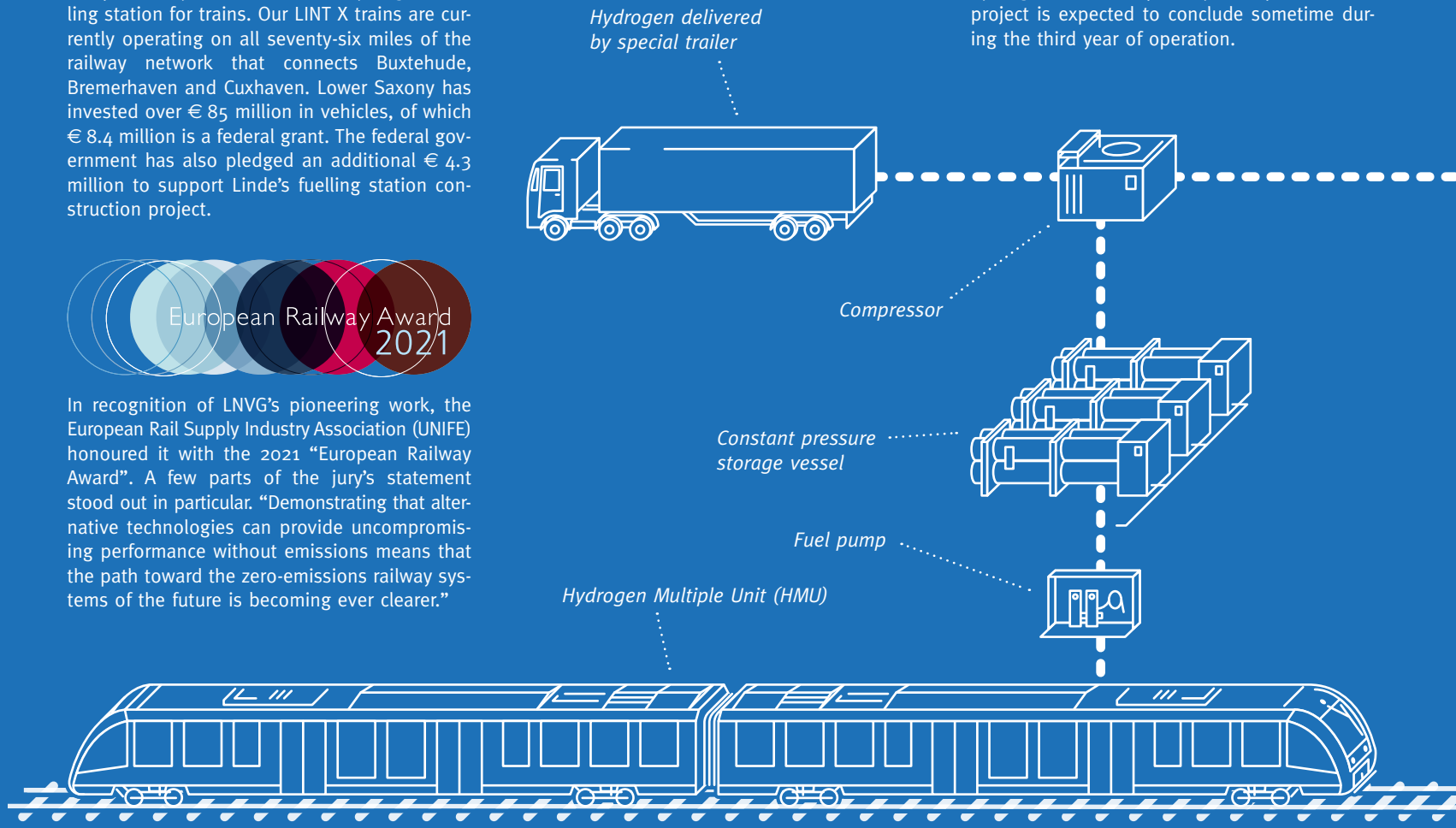
Acclaimed World Premiere

Bremervörde is located right in the heart of the first railway network in the world served exclusively by hydrogen fuel-cell-powered trains. To ensure the longevity of this project, it was accompanied by the world's first hydrogen fuelling station for trains. Our LINT X trains are currently operating on all seventy-six miles of the railway network that connects Buxtehude, Bremerhaven and Cuxhaven. Lower Saxony has invested over € 85 million in vehicles, of which € 8.4 million is a federal grant. The federal government has also pledged an additional € 4.3 million to support Linde's fuelling station construction project.

European Railway Award 2021

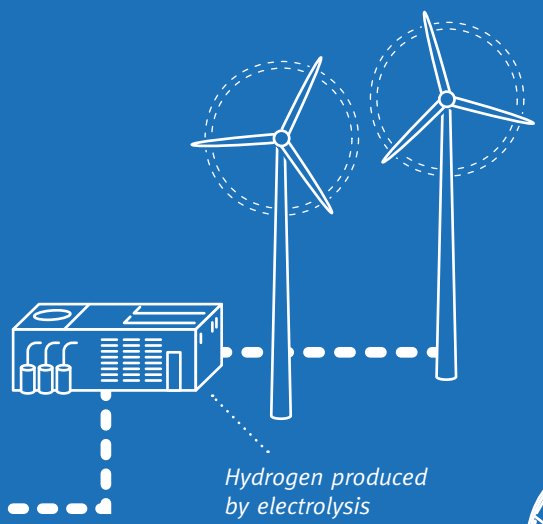
In recognition of LNVG's pioneering work, the European Rail Supply Industry Association (UNIFE) honoured it with the 2021 "European Railway Award". A few parts of the jury's statement stood out in particular. "Demonstrating that alternative technologies can provide uncompromising performance without emissions means that the path toward the zero-emissions railway systems of the future is becoming ever clearer."

Phase One
Initially, the trains will be refuelled with hydrogen from chemical plants located in Stade. On average, the station would need two or three hydrogen deliveries per day. This phase of the project is expected to conclude sometime during the third year of operation.



Phase Two
By the third year of operation, we expect to be producing our own hydrogen locally in Bremervörde using electrolysis. The electricity we use will come from solar and wind farms. The immediate objective is to increase the share of “green hydrogen” to thirty-five percent.

Phase Three
Ultimately, we hope to boost that all the way up to ninety-five percent. A time frame has yet to be set. Developments in energy costs will be a major factor, no doubt.



Bremervörde hydrogen fuel filling station

Max. daily refuelling capacity:	1,600 kg of hydrogen per day
Total hydrogen stored on site:	1,800 kg
Fuel tank capacity:	2 x 130 kg
Operating pressure:	5,075 psi
Average tank refuels per day:	~ 12
Hours of operation:	Around the clock
Total capacity:	~ 4,590 kg of hydrogen (incl. H_2 Trailer)

Ramping up operations

- Start of operation: Summer 2022
- First four trains operational starting August 2022
- Roll out of additional ten trains slated for late summer
- All fourteen trains will be in operation by December 2022
- Trains will be in service 365 days a year
- Rolling stock has an estimated lifespan of thirty years

LINT X hydrogen fuel-cell multiple unit

- Year of construction 2022
- 156 seats
- Maximum speed: 87 mph; Operational speed on EVB railway network: 50–75 mph
- Total mass: ~ 119 t
- Trainset length: 180 ft
- Fuel cells on board: 2
- Peak performance: 2 x 397 kW
- Two 130 kg hydrogen tanks
- Operating range: 680 miles

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Say Goodbye to Diesel—The Future Belongs to Hydrogen!

By Thomas Nawrocki, LNVG's Director of Vehicle Management

If there's one thing we're sure of, it's that the future of the Wese-Elbe network belongs to hydrogen. The LNVG's transition away from diesel has been in motion since 2012/2013. How did that come about?
Back then, we found ourselves confronted by several pivotal questions.

What will the price and supply of diesel look like in thirty years and will it still make sense to use DMUs on regional rail routes that are not electrified? Are diesel vehicles still cost effective over a thirty-year service life, especially when you consider MRO?

It became obvious that we needed to find a diesel alternative. Fuel cell propulsion presented an attractive solution. Even more so as people started treating climate action, including curbing greenhouse gas emissions, as an imperative. Back then, alternative battery and fuel propulsion technologies were still in their infancy.

Hydrogen fuelling station groundbreaking ceremony on 28 July 2020. Starting left: Mathias Kranz (Linde), Dr. Jörg Nikutta (ALSTOM), Thomas Nawrocki (LNVG), Carmen Schwabl (LNVG), Holger Buse (EVB), Joachim Heider (Linde)

We think this "modest" project will prove that hydrogen is a true energy alternative whose time for market maturity has come. If we succeed, I have no doubt that our drive technology has a long and competitive future. Over twenty years of rolling stock management prepared LNVG for the necessary upgrade to a new generation of vehicles as well as for the long-term MRO and energy security commitments that came with it. Our objective has always been to design a fully integrated system.

Only around sixty percent of the German railway system is electrified at the moment. The truth is that electrification simply isn't economically feasible yet everywhere, especially on low-volume routes. If you can't electrify the track, then the obvious solution is to electrify the trains themselves. There are three main arguments in favour of regional railways employing fuel cell multiple units on routes they don't plan to electrify in the medium or long term:

First: CO_2 Reduction

We began treating climate change as a priority long before the Paris Agreement was adopted in 2015. Our overriding aim is to slow global warming by reducing carbon emissions. The transport industry will need to carry a major part of the load.

LNVG's fuel cell trainsets are leading the way. All of the DMUs currently in our fleet are slated to be phased out. Once that process is complete, running our trains will no longer produce CO_2 locally. The DMUs that operated on the Weser-Elbe network alone used around 1.6 million litres of diesel annually. Retiring them amounts to reducing CO_2 emissions by around 4,400 tons every single year. While that's only a modest share of the transport industry's total CO_2 output, this project is only the beginning and its most important achievement is proving that it can be done.

"This project is only the beginning and its most important achievement is proving that it can be done."

During the initial phase of our operation, we will be using chemical industry waste hydrogen as our fuel source. It doesn't have to be made extra but can be re-used sustainably instead. First, the hydrogen needs to be transported by truck to the Bremervörde fuelling station.

The second phase of the project is set to begin in 2024. By then we want to be producing our own "green hydrogen" on site using solar and wind power. An electrolysis system installed adjacent to the fuelling station in Bremervörde will ensure an uninterrupted supply of power to what will be a truly zero-emission fleet. Producing power on site will save an additional 4,600 tons of CO_2 every year. That comes out to 9,000 tons of CO_2 less being emitted annually because of the effort we've made.

We are also taking advantage of the fact that hydrogen can be stored. Any time the wind blows or the sun shines, hydrogen is being produced. If weather conditions aren't cooperating, there is plenty of hydrogen stored on site to ensure vehicles are sufficiently supplied. By then, the chemical industry waste hydrogen will merely be the fall-back solution.

Second: Reducing Fossil Fuel Consumption

The days of powering everything with fossil fuels are numbered—the same is true for their economic viability. We foresee the availability of fossil fuel supplies continuing to dwindle and recognize the need to reduce our dependence on them. Current geopolitical and global economic developments have only served to amp up the pressure to seek alternatives and shift away from fossil fuels once and for all.

Currently, DMUs operating on the Weser-Elbe Line travel more than one million miles per year. Hydrogen fuel cell trains are going to replace all 1.6 million litres of diesel that LNVG trains consume today. Those are fossil fuels which we will never need to produce or purchase every again! Once we can start producing enough hydrogen locally, we'll not only be fully decarbonised, but we will be totally energy independent as well. This is a one-of-a-kind opportunity to finally break our dependence on fossil fuels and to make a major contribution to reducing their use.

Third: Economic Viability Calculations Based on Thirty-Year Train Service Life

People ask us about the economic viability of the LNVG project all the time. I can't really offer them much in the way of hard numbers at the moment. We just haven't had the chance to gather enough data yet. Based on what we know about our diesel vehicles and from the data the pilot vehicles gave us, LNVG projects fuel cell propulsion to be more economical over the entire lifespan of a vehicle, especially since it's not clear how the cost of diesel will develop over time.

"LNVG projects fuel cell propulsion to be more economical over the entire lifespan of a vehicle."

Anyway, comparing traditional diesel traction to fuel-cell-powered traction is like comparing apples and oranges. When you compare the two, it's important to remember all the costs not directly priced in—especially the carbon footprint. Fuel cells win that competition by a mile. For the time being, public funding remains key to their cost effectiveness.

Hydrogen is the most common element on our planet. It can be produced. It's the by-product of a lot of important industrial processes. It can be stored in large quantities. It's basically an unlimited energy resource. That's why so many people have started focusing on hydrogen as a possible energy transition solution. A hydrogen-free mobility industry is basically unimaginable at this point. Hydrogen is an attractive fuel especially if you are a small to medium size fleet operator serving a limited area, regardless of whether you specialise in freight or passenger transport. There's so much more that can be done. Coupling sectors (e.g. mobility with energy or mobility with natural gas) would add a lot of value by increasing hydrogen's application opportunities and by expanding its overall market. It would also be a great way to control long-term costs and to improve efficiency.

LNVG aims to use its fuel cell multiple units to prepare its innovative traction technology to break into the regional railway market while paving the way for future innovators to replace DMUs. We would love it, by the way, if you decided to copy us.

LNVG

Weltpremiere Wasserstoff

FAQs

1) How does refuelling a multiple unit work, exactly?

After intensive training, drivers and staff have managed to cut the time it takes to refuel a LINT X at the Bremervörde station to somewhere between twenty and thirty minutes. The refuelling process itself is relatively straightforward. Anyone who wants access to the fuelling station needs a unique fuel card. Then all you need to do is connect the fuel pump to the filler neck on the train. Press a button and the LINT X tank starts filling up automatically and then stops when it's full.

2) What kind of the safety precautions are there?

Even though fuelling the trains is easy, there are a lot safeguards and safety precautions in place. Each driver has a unique fuel card and you can't use the fuelling station without it. Before hydrogen really starts flowing into the vehicle, the system conducts a shock test to check component integrity and ensure that the connection is properly fastened. Simultaneously, the system determines how much gas is in the tank. There is an interface connecting the train to the fuelling station, which ensures information is constantly passed back and forth. Should the system detect any deviation from the standard operating procedures or notice something abnormal going on, either side has the ability to shut off refuelling automatically.

3) How is the electricity that powers your multiple units produced?

The LINT X is equipped with a fuel cell that uses hydrogen and oxygen to generate electricity. Traction batteries store the initial charge and provide power to the traction motors. Like all forms of electrified rail, the LINT X also recovers electricity through regenerative braking, which it feeds back into the traction batteries to boost their power supply.

Partners and Institutional Participants

Alstom

From high-speed trains, metros, monorails, trams, to turnkey systems, services, infrastructure, signalling, and digital mobility, Alstom offers its customers the broadest applications portfolio in the industry. There are more than 150,000 Alstom passenger trains in service across the globe. Headquartered in France, Alstom is present in seventy countries and employs more than seventy thousand people worldwide.

The Federal Ministry for Digital and Transport

National Innovation Programme (NIP II) market activation measures: The Federal Ministry for Digital and Transport sponsors measures aimed at advancing fuel cell propulsion in Lower Saxony through the National Innovation Programme for Hydrogen and Fuel Cell Technology. Under this programme, up to € 8.4 million in federal support was granted. NOW GmbH is the coordinator for the funding directive, while Project Management Jülich (PtJ) is responsible for management and implementation.

EVB

The Eisenbahnen und Verkehrsbetriebe Elbe-Weser GmbH railway and bus company (EVB) is one of Northern Germany's premier passenger and freight transport operators. Every year, EVB's highly-committed team of more than five hundred and fifty members carries over two million passengers by rail. They also ensure that over four million bus passengers per year reach their destinations throughout the Elbe-Weser triangle safely. The EVB owns and operates its own railway network as well as offering haulage services nationwide.

LNVG

The Lower Saxony Transport Authority (LNVG) administers regional rail transport all the way from the North Sea to the Harz for which it receives around € 300 million in compensatory payments from independent train operator companies (TOCs) annually. You could say that the LNVG isn't just on board the fuel-cell technology train but that it's driving it. LNVG owns more than four hundred railway vehicles, which it leases to TOCs.

Linde

Linde is a leading global industrial gases and engineering company with € 26 billion revenue in 2021. From life-saving oxygen for hospitals, to high purity and speciality gases for electronics manufacturing, to hydrogen generation, and beyond, Linde-made industrial gases are used in countless applications. Linde's portfolio also includes state-of-the-art gas processing solutions.

ALSTOM
• mobility by nature •

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evb

LNVG Landesnahverkehrsgesellschaft Niedersachsen mbH

Linde

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