FUTURE FUELS

WHAT FUELS WILL WE BE USING IN THE FUTURE?

And where will they sit in a sustainable multi-fuel ecosystem?

A series of articles from Jorgen Pedersen, Director of New Technology, SYSTRA

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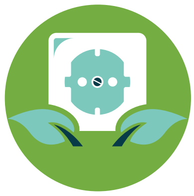
An Analysis of Future Fuels

The prevalence of the privately owned vehicle and the fuel it burns has also contributed to horrible air quality, declining health, premature deaths, work related stress, huge tax-payer expense on infrastructure, and even if we were to ignore the carbon dioxide, we still have Nitrous Oxide, brake dust and tyre emissions some of which and now considered equally as harmful as CO_2.

Carbon Friendly Electric Vehicle



The introduction of the Electric Vehicle as a carbon friendly private transport solution has been hailed a clear winner against other lesser-known technologies with private electric vehicles currently account for about 20% of all new vehicles being bought in the UK. But the question is, does it deliver against those promises? Perhaps if all our electricity came from renewable sources, perhaps if we didn't destroy the planet looking for Lithium, Cobalt and Nickel for Lithium Battery production, perhaps if Lithium batteries were a little more stable, perhaps if Electric Vehicles were not on average 20-30% heavier than their conventional internal combustion engine (ICE) siblings, perhaps if the lifespan of an in-vehicle battery was a bit longer, then perhaps it would be easier to justify this transition. But unfortunately, life and the pursuit of happiness isn't that simple.

Battery Electric Vehicles

In addition, there is little to suggest that Battery Electric for heavy haulage is the way to go. The size, weight and range of such a vehicle renders most applications impractical. For example, Volvo have a line of BEV trucks, and if one takes the time to read their FAQ's they are extremely honest about their capabilities. They discuss carbon reduction, carbon footprint, range, charging time and even battery weight. They stop short of indicating the lifespan of their truck batteries, which is difficult to predict as there are many external factors at play such as charging methods, heat, cold, load etc. But suffice it to say, that the general configuration is 2-6 batteries weighing about half a ton each. Range is about 200 miles (300KM) which is short, and charge time with AC chargers should be around 9 hours and just 2 hours with a DC charger, which I'm sure will depend on the charger capacity.

Electric Road Systems (ERS)

This suggests that for many freight and heavy haulage applications BEV's probably won't provide a long-term answer, but if not battery then what? Well in the Volvo FAQ's there is also some reference to Hydrogen fuel cell technology. Siemens are also pursuing Electric Road Systems (ERS), of which there are three main contenders, overhead catenary lines similar to those used by the rail industry, live rail systems, and embedded induction loop systems but all these options have both advantages and disadvantages. Are we comfortable with the risks (perceived or otherwise) with having even more open electric cables on our world, or being irradiated with electro-magnetic radiation from inducted loops? Taking this approach are we simply kicking the proverbial can a bit further down this well-travelled road? And then there is the huge amount of infrastructure that would need to be implemented to deliver any one of the ERS systems that are being proposed. After 20 years of rail electrification only about a third of the UK rail networks 9824 miles has been electrified. The Strategic Road network provides about 4500 miles of just trunk routes and motorways but comprises only about 2% of the overall road network of the UK. Have we considered whether this is an efficient use of resources, tax-payer money, or even the carbon footprint required to embark upon such a massive infrastructure project? Can the national grid which is still heavily reliant on fossil fuels (57%) support this additional load, without the need to resort to burning more fossil fuels?

> "Please don't misunderstand me, I'm not an advocate of one technology over another, I strongly believe that to be successful we will need to embrace different technologies for different applications, and that all technologies will have their place in the new dawn of a technology hybrid fuelled world."

Hydrogen fuel cell technology

I don't believe that sufficient emphasis has been placed on Hydrogen, either in Fuel cell technology or in terms of Hydrogen ICE's which can immediately remove CO_2, but admittedly will still emit some NO_X. But surely, it's better to incrementally remove CO_2 emissions while still producing some NO_X emissions rather than continue to pollute the planet to the extent that we are while we wait for a zero-emission technology which might still be a decade or more out? There is also the added promise of zero emission biofuels, and whether these will deliver as promised, and whether the process of manufacture doesn't add significantly to our carbon footprint.

Is Net Zero Plan Achievable

Other than the grandiose goal to be carbon neutral by 2050 do we have an achievable sustainability net zero plan? Are we being led by big businesses that have a vested interest to promote their own technologies rather than reviewing the facts of what is right, wrong, beneficial to best support the UK business and consumer requirements. Is the information we are receiving from big business accurate in terms of its carbon footprint, do we understand our return on carbon footprint if we are to undertake some of these proposed large infrastructure projects? Are we looking at our carbon utilisation holistically when we are making these core decisions? Is the information we are being exposed to the most accurate reflection of reality?

SYSTRA will be developing a series of articles to discuss in more detail future fuels and where they may sit in a sustainable multi-fuel ecosystem, which will help to answer some of these questions.

> "I'm not suggesting that we have all the answers, but I am suggesting that perhaps the information we are being exposed to perhaps isn't necessarily the most accurate reflection of reality."

Electric Avenue

Jorgen has been pulling together curious minds to discuss the technology surrounding the fuels that could help the transport sector reach Net Zero by 2050. In this article he lifts the lid on electric vehicles from their origin, their green credentials, and of course their future use.

Are we barking up the wrong green tree or should we be seeking alternative green options when it comes to future vehicle technologies? Current thinking on future vehicle technologies is firmly focused on Electric Vehicles (EV), whether those are Battery Electric Vehicles (BEV) or Hybrid Electric Vehicles (HEV). While 20% of vehicles purchased in the UK during 2022 were EVs, neither type come without significant side effects which are not being discussed enough.

There is no doubt that when it comes to new vehicle technologies, EVs are winning the race in comparison to Hydrogen Fuel Cells and Hydrogen Internal Combustion Engines. Is this because they are simpler, more efficient, easier to produce, more convenient or perhaps better marketed?

Let's start by examining the rise of the EV market

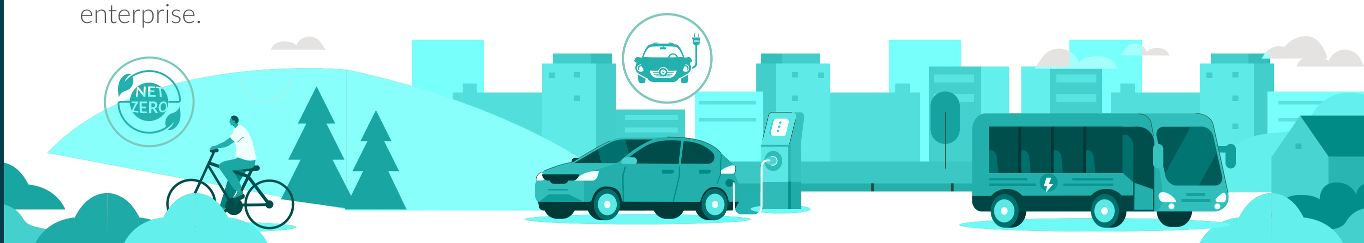
You may be surprised to learn that experiments with electric vehicles began as early as the 1830s when a Scottish built battery powered seven-tonne train pulled a six-tonne load over a staggering 1.5miles at 4mph. Further development of electric vehicles happened during the 1880s when a succession of inventors created motorised tricycles and trains. Electric trains were also introduced for deep underground mines, these were considered safer and pollution free, therefore protecting miners from harmful gases. By 1897 the first electric powered taxis appeared in London, and in New York a year later and were considered ideal for city living.

The first modern hybrid car was the Armstrong Phaeton, developed in Bridgeport Connecticut in 1896. It was powered by 6.5L 2-cylinder petrol engine, coupled to a DC generator and boasted many world firsts, including an automatic transmission and an electric start, not to be seen on any other vehicles for decades to come.

The Phaeton was quickly followed by Ferdinand Porshe's Semper Vivus displayed at the Paris World Fair in 1900 and became more widely available in 1901. The Vivus used a petrol engine to power a generator to charge 44 x 80V lead acid batteries that powered the small electric motors attached to both front wheels (this later changed to be on all 4 wheels). It could achieve speeds more than 10mph and had an 80-mile range. Roll forward 100-years to 1997 when Toyota introduced the first successful mass-produced hybrid car – the Prius.

Back in the 1990s the biggest issues preventing widespread EV adoption was their range which enabled intra-city trips only, the lack of battery charging infrastructure and the amount of time required to re-charge. Sound familiar?

In the 1900s the race to develop electric and hybrid vehicles began because petrol was only available in limited supply from chemists. It wasn't until 1905 that the first petrol station was built in St Louis, Missouri, followed 2-years later by the second in Seattle, Washington, both were funded by private enterprise.



Todays international mandate

Despite today's international mandate to develop carbon friendly vehicles, it has largely been left to private enterprise to develop the modern EV as well as the infrastructure to support them, these companies have had to have deep pockets.

Tesla as well as being the first mass producer of popular EVs, was also the first company to successfully deliver a fleet of superchargers aimed at rapid charging for longer-distance travel. So far, Tesla have installed more than 44,000 superchargers globally and 35,000 slower chargers at large trip attractor locations such as shopping malls to meet demand.

Should we rely so heavily on the private sector to develop the necessary infrastructure? Are consumers best served by the private sector to provide the best technologies or most carbon friendly solutions? Are we aware of the impact that new technology has on our environment, our health and our planet? Is there better or alternative technology that should be further investigated, moved forward, embraced, and promoted?

EV technologies

There is no doubt that the introduction of EV technologies has helped us focus on the need for carbon friendly transport solutions and has given us a collective awareness of our sustainable transport needs. But will it deliver on our net zero goals?

Battery technology is not sufficiently mature enough to provide the range that is expected from ICE petrol- and diesel-powered vehicles. New solid-state batteries, and liquid flow batteries may have the potential to increase range considerably, but these are still many years away.

BEV's are on average 30% heavier than their conventional ICE siblings, this means they cause more road degradation, and significantly more brake-dust and tyre particulates that can enter the air we breathe which is being suggested could be equally or more damaging to our health than $C0_2$ and NO_X.

Lithium-Ion batteries which are used in most EVs have an optimum temperature range between 0° and 27°C, when the battery is exposed to temperatures below freezing or above 27°C performance can be severely compromised. In addition, Direct Current Rapid Charging (DCRC) while more convenient has been proven to have a detrimental impact on the overall lifespan of an EV's battery.

Impact on the National Grid

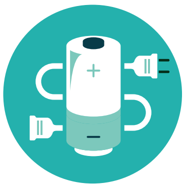
Another concern is the impact of plugging millions of EVs into the National Grid when everyone gets home from work? There are technologies that can now support Battery to Grid to ensure that the grid doesn't become overloaded, but consumers are struggling to understand how that will work.

There are many unanswered questions. How will we accommodate a fair and equitable exchange in a Battery to Grid environment? Plus, would a higher calling from the National Grid take priority over your vehicle when you most needed it?

Pros and cons of future fuels

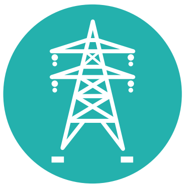
When considering the pros and cons of future fuels, we must consider the environmental impact of a wholesale shift in demand for lithium-Ion batteries. In a recent article in Forbes Magazine, it was suggested that increased demand for lithium, cobalt, graphite, and nickel will require developing more than 300 new mines, over and above our capacity to recycle old batteries. Do we have any idea of the ecological impact that opening so many mines would have, let alone the carbon footprint that would be attributed to such activity? Do we fully understand the full carbon footprint of BEV's? Or perhaps by simply ignoring it we can avoid answering this difficult question since none of the minerals required will be mined in rural Britain.

BEV technology



If for a moment we turn to our freight needs, can BEV technology be used to support our heavy haulage needs? The answer is a clear no. Current Battery technologies will not be able to provide the performance or range for pulling heavy loads. Volvo has a line of Battery Electric Vehicle (BEV) trucks, and if one takes the time to read their FAQ's they are extremely honest about their capabilities. They discuss carbon reduction, carbon footprint, range, charging time and even battery weight. They stop short of indicating the lifespan of their truck batteries, which is difficult to predict based on use case, charging methods, heat, cold, load etc. But suffice it to say, that with the general configuration of 2-6 batteries weighing about half a ton each, a range is about 200 miles (300km) which is short, and a charge time with AC chargers of around 9 hours and just 2 hours with a DC charger, which I'm sure will depend on the charger capacity. With these limitations it would suggest that they are not going to replace the current UK heavy haulage fleet anytime soon.

So, where are we?



At present BEV sales in the UK constitute about 20% of all car sales. By December 2021, the UK's renewable energy generation was 42%, meaning that 58% of our electricity supply is dependent on fossil fuels. Can the National Grid support the level of BEVs that are expected over the next few years? While renewable energy production is increasing year-on-year, it doesn't seem to be able to match our appetite to consume electricity.

We know we can increase our energy capacity to accommodate demand, but at what financial, ecological, and environmental cost? How will delivering the required new infrastructure impact Net Zero?

> "My objective in writing this series is to stimulate a healthy debate on how we should approach future fuels, and perhaps be a little more open minded to the opportunity for alternative options to those that are currently being presented to us. I'd welcome your views, including those which are at odds to mine, it is only through debate and scientific investigation that we will make the right decisions to reach net zero. The next article will explore hydrogen as a fuel in more detail."


H2
Hydrogen
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Hydrogen

Determined to raise the level of debate around which fuels will power transportation in the not-too-distant future, Jorgen delves into hydrogen technology and asks if this emerging fuel technology can be used in the short term to help meet Net Zero by 2050.

Hydrogen and the suggestion that it could be a future fuel seems to attract polarised views with some suggesting that it is the future whilst others say it has been tried, tested and failed, for a number of different reasons: that the production of hydrogen is energy intensive; that hydrogen is dangerous, more dangerous than petrol; is significantly more difficult to contain than petrol; and, that the creation of hydrogen is not carbon friendly.

Let's explore each of these in turn. But first I have to convey that I am not an advocate of any one specific fuel or technology, in fact I strongly believe that a hybrid landscape of fuels and technologies tailored to niche markets such as freight, aviation, public transport or the private car will be the future.

How energy intensive is hydrogen to produce?

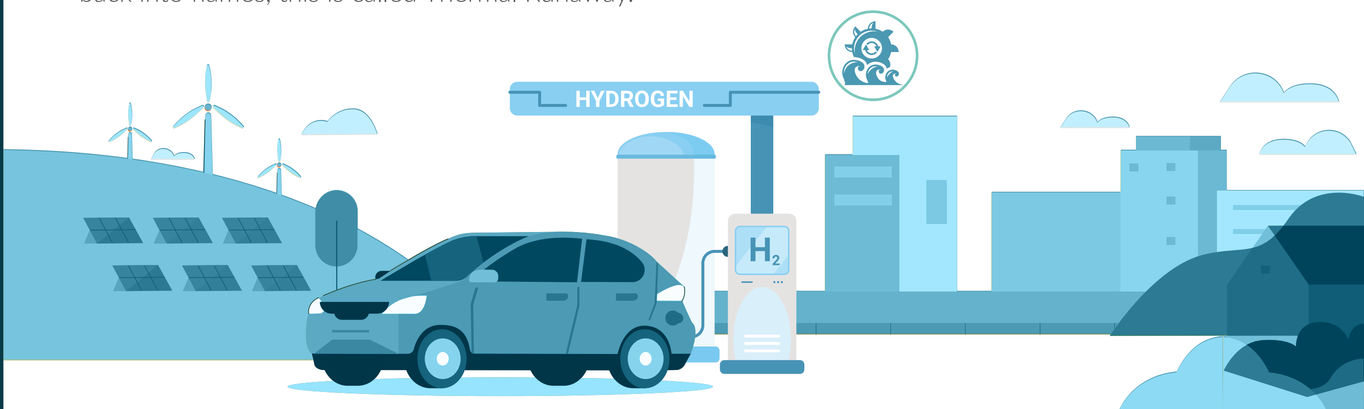
The conversion process from water to hydrogen through electrolysis is conventionally very energy intensive requiring about half of the energy created for the conversion process. The 'Steam Methane Reforming Process' while 74-85% efficient still requires the use of fossil fuels and has therefore been discounted as a viable long-term approach.

However, newer technology innovations such as 'zero gap' electrolysis have increased efficiency to 75-80% and the Australia company Hysata is now claiming 95% efficiency by using capillary action to ensure that bubbling cannot not occur around electrodes. If the claims are correct this will prove even more efficient that EV charging which in general achieves 93% efficiency. When coupled with renewable energy sources this process can produce carbon friendly and efficient hydrogen production.

Hydrogen can be created using renewable sources such as offshore wind turbines when they would otherwise be tethered or spinning aimlessly at night. Any excess energy from these sources could be used to create hydrogen, which would provide a renewable and storable energy source.

Is hydrogen dangerous?

Hydrogen has an unusually broad flammability range (Stoichiometric Ratio) when mixed with air, between 4-74% requiring hydrogen units to be fully sealed to prevent hydrogen seepage. But, has anyone tried to extinguish a lithium polymer battery? It is almost impossible, one can smother it, immerse it in water, but as soon as air is re-exposed to the elements the chemical reaction continues and the battery can burst back into flames, this is called Thermal Runaway.



Is hydrogen difficult to contain?

Hydrogen has a very small molecule size, some will say that the size of the hydrogen atom makes it virtually impossible to develop hydrogen vehicles because the hydrogen atomic radius makes it virtually impossible to contain. But let's explore that in a little more detail. Hydrogen has an atomic radius of 0.53, Helium 0.31, Neon 0.38, Fluorine 0.42, Oxygen 0.48, Nitrogen 0.56. So, it's small but not necessarily the smallest. Furthermore, helium, neon, oxygen and nitrogen have all been used in commercial applications including glass purification, petrochemical refinement and semiconductor manufacture for decades.

Can hydrogen be stored easily?

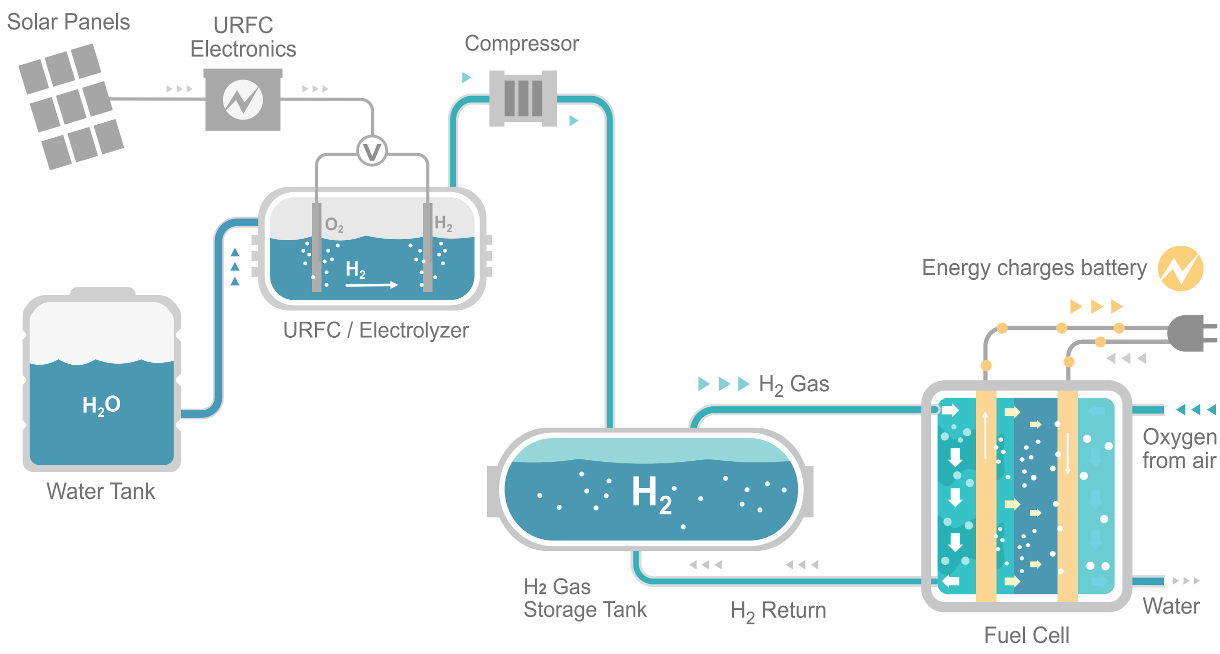
The main difference is that unlike electricity, and despite the small molecular size, hydrogen can be stored in significantly larger quantities. The molecular size presents challenges and will require additional safety measures if hydrogen is to become more mainstream. Using renewable energy sources which are not being fully utilised, hydrogen could be produced, stored and made available to fill energy gaps.

Is the creation of hydrogen carbon friendly?

Finland is the world leader in the production and utilisation of 'green hydrogen' – that is manufactured from sustainable sources using sustainable power. In Norway, the Kvaerner process first developed in the 1980s produces carbon neutral 'green hydrogen'. The efficiency of both these processes are being improved upon year-on-year and it is predicted that by 2030, energy conversion via electrolysis will be as high as 82-86%, which is not wildly dissimilar to the energy transfer loss of charging an electric vehicle.

There is some speculation that the production of 'blue hydrogen' (produced using both renewable and fossil fuel energy sources) can have a higher carbon footprint that using conventional hydrocarbon fuels. However, Blue Hydrogen generation should not be discounted especially when produced using currently available carbon capture and storage (CCS) processes or when using autothermal reformers (ATR) with integrated carbon capture. Both of these processes have been shown to reduce the carbon footprint to below that of conventional fossil fuels.

Green Hydrogen Fuel Cell Energy



Is using hydrogen cost-effective?

Unlike other countries the UK has been slow to embrace the use of hydrogen as a fuel unlike Finland which has already gone all-in with hydrogen production, and now has the biggest hydrogen production facilities in Europe. Utilising hydrogen fuel cells Finland believes that this fuel will change not only our future transportation landscape but can be used for everything from residential to commercial heating applications, and even industrial ore smelting.

The City of Edmonton, Canada, recently announced an investment of $470m on a blue hydrogen production facility. In the USA, California started to build a large hydrogen production facility in 2021 which will turn waste plastics into hydrogen and will come on-line later this year. The Californian facility adds to a growing US national hydrogen production network including New York, Georgia, and Tennessee. Closer to home, Scottish Power has announced its intention to build a £150m hydrogen production facility at the Port of Felixstowe, which will provide sufficient fuel for 1300 HGVs.

Are hydrogen vehicles available?

Some hydrogen vehicles are in fact available today. The Hyundai Nexo and the Toyota Mirai were released in 2018 and 2015 respectively. The Mirai had sold 10,000 units up until 2019 mainly in California, Denmark, and Norway. And, there is of course the BMW iX5, currently in development.

Hydrogen can be used as a fuel like petrol and used to power modified or redesigned internal combustion engines (ICE). In fact, hydrogen has the best power to weight ratio of any other fuel. On the plus side, since hydrogen is not a hydrocarbon it does not produce CO_2, however its main drawback when burned it that it produces NO_x (nitric oxide and nitrogen dioxide). That said, with the introduction of more efficient NO_x reduction systems including exhaust gas recirculation and selective catalytic reduction, NO_x emissions can be significantly reduced.

Several car manufacturers have already realised the benefits of hydrogen fuelled ICE and are producing vehicles as well as retro fitting. This is not new technology the earliest example of a hydrogen ICE was in Russia during WWII when 200 vehicles were retrofitted to run on hydrogen when petrol and diesel became unavailable.

Over the last few years one of the word’s largest manufacturers of construction equipment JCB has been redeveloping their engines to use standard components to run on hydrogen. These vehicles are already being used across a number of commercial applications from mining to farming. And let’s not forget the Toyota GR Yaris H2, while not yet commercially available has proven itself a force to be reckoned with on the world rally car circuit.

HYDROGEN USED FOR COMMERCIAL APPLICATIONS

Hydrogen must be part of the solution

Given that the average replacement time of a new vehicle is 15-years and even if we cease to purchase new petrol or diesel cars by 2030, vehicles burning petrol will still be on the road well past 2050. Providing an alternative to petrol which also removes CO_2 seems to be the best steppingstone towards net zero.

It's unrealistic to consider converting all vehicles to burn hydrogen, but for freight this could provide a quick and efficient opportunity to provide an alternative to battery electric vehicles whilst maintaining our carbon reduction goal.

At present there are just 12 hydrogen filling stations in the UK, to get this started we would urgently need a commitment to invest in hydrogen production and for it to be readily available as part of the existing filling station infrastructure mix. A purpose-built network that could reasonably easily accommodate multiple technologies including hydrogen fuel cell, hybrid vehicles and hydrogen ICE vehicles.

> "My objective in writing this series is to stimulate a healthy debate on how we should approach future fuels, and perhaps be a little more open minded to the opportunity for alternative options to those that are currently being presented to us. I welcome your views, including those which are at odds to mine, it is only through healthy debate and scientific investigation that we will make the right decisions to reach net zero. In the next article we will be exploring Synthetic Fuels to better understand their benefits and disadvantages."

Jorgen Pedersen

During his career Jorgen has been responsible for the delivery of several innovative and business transformational ITS programs across the breadth of the traffic and transit sectors. Including connected and autonomous mobility, fare payment systems, traffic management systems, advanced traveller information systems, integrated corridor management solutions (ICM), Smart City initiatives, MaaS, On Demand and Micro-transit solutions, as well as some exposure to vehicle to infrastructure (V2X) projects.

Jorgen recently returned from the US to join the SYSTRA team as the Sector Director, Transport Technologies. The role concentrates on using a wide array of transport technologies and transport approaches to deliver improved travel options covering public, active and private modes to improve our carbon footprint.

During the 13-year tenure at TfL, Jorgen was the Head of Realtime where he delivered the award-winning London Journey Planner and was responsible for the change of emphasis from real-time to predictive traveller information.

SYSTRA

Find out how SYSTRA can assist you in Future Fuels:

JORGEN PEDERSEN
New Technology Sector Director
m: +44 7709 483104
e: jpedersen@systra.com