A Guide to Alternative Fuels for Non-Road Mobile Machinery Used in Ports

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The British Ports Association is the national trade body for UK ports and harbours. Our members handle 86% of the UK's seaborne trade and as well as supporting other important maritime activity from offshore energy to fishing and marine tourism and leisure.

This guide was prepared by Jackie Savage and Emily Stevens of the **Zemo Partnership** for the British Ports Association.

Introduction

Decarbonising the NRMM (non-road mobile machinery) sector by transitioning to zero tailpipe emission technologies will be particularly challenging due to the diverse range of equipment types, long asset life, hours of operation, and demanding power and energy density requirements. Sustainable low carbon fuels offer an immediate solution for reducing greenhouse gas emissions. This guide provides a high-level overview of a range of low carbon liquid and gaseous fuels that could serve to replace retail (predominantly fossil) diesel in non-road mobile machinery deployed in UK ports, over the next five years. These fuels will continue provide greenhouse gas abatement in legacy equipment up to and beyond 2045.

Included are a variety of biofuels and low carbon hydrogen pathways. For each low carbon fuel, information has been presented for six characteristics related to: production method, application in heavy-duty engines, UK market supply chain and deployment, operational considerations, greenhouse gas (GHG) and air pollution emissions compared to diesel, and the financial considerations for fuel and equipment costs compared to diesel. Similar information for electric NRMM has also been included for comparison purposes. A summary is provided of future fuels, forecast to come to market at scale from 2030 onwards. Examples of UK initiatives related to certifying sustainable biofuels and retrofit equipment for air pollution control are additionally provided. Examples of low carbon fuel deployment, electrification and hydrogen in UK Ports, and electric and hydrogen NRMM equipment, can be found in the Appendix.

Biofuels

Policy Landscape

The UK Renewable Transport Fuel Obligation Order (RTFO) was introduced by the Department of Transport (DfT) over fifteen years ago to deliver reductions in greenhouse gas emissions from fuels used in road transport and non-road mobile machinery. In 2022 renewable fuel made up 6.8% of total road and NRMM fuel supplied in the UK.

The RTFO requires the renewable fuel supply chains to meet GHG emissions and sustainability standards to be eligible under the scheme, these are –

- Greenhouse gas emissions savings of more than 65% compared to fossil fuel. The target is based on lifecycle greenhouse gas emissions. This accounts for growing an energy crop or collecting waste, manufacturing the fuel, transportation, dispensing and combustion.

- Growing crops for biofuel production should not lead to loss of biodiversity or high carbon value land. This ensures protection of sensitive ecosystems such as tropical forests, wetlands and peat land.

Biofuel suppliers can demonstrate that their raw materials and supply chain meet these requirements through certification under voluntary sustainability schemes such as the International Sustainability and Carbon Certification (ISCC). These schemes require a chain of custody to be in place with regards to waste feedstocks, giving assurance of their origin.

When biofuels undergo combustion, exhaust CO_2 emissions are accepted as zero. This is because CO_2 has already been taken up by plants during their growing process, essentially producing a closed loop in the carbon cycle. Biofuels produced from biogenic waste typically have a much lower carbon intensity than those made from energy crops grown specifically for fuel production. In some cases, the manufacture of biofuels can result in net zero or even negative GHG emissions through the avoidance of methane emissions being released to the atmosphere by certain types of organic wastes.

Biodiesel (FAME)

Production	Biodiesel, also known as FAME (Fatty Acid Methyl Esters), can be produced from a variety of biomass feedstocks including energy crops, such as soy and rapeseed oil, and biogenic wastes and residues, such as used cooking oil, tallow oil, fats and greases. Biodiesel is produced via the process of transesterification. Biodiesel can be supplied as 100% renewable fuel, or as a blend with mineral diesel such as B20 (20% biodiesel) and B30 (30%).
Application in heavy duty engines	FAME is required to meet specific European fuel specifications. B100 must comply with EN14214 and B20/B30 with EN16709. Heavy duty engine manufacturers have different positions regarding biodiesel compatibility and equipment warranty. Further information on engine approval can be found in Zemo's Renewable Fuels Guide Appendix but it is recommended that operators contact the manufacturer to confirm prior to using biodiesel. It is likely that equipment can run on B20 and B30. Equipment modifications would be required for B100, however there are none currently offered by manufacturers.
UK market - supply chain and deployment	There is an established biodiesel market in the UK, with a high proportion of biodiesel blends used in heavy-duty applications produced from biogenic waste feedstock. Deployment in the NRMM sector is primarily as a renewable fuel for generators. Increasing volumes of biodiesel will become available as the demand for diesel in the UK car and van fleet declines with increasing electrification.
Operational considerations	Biodiesel requires additional house-keeping compared to conventional diesel. Biodiesel is affected by cold temperatures resulting in the need for heated tanks, fuel lines and dispensing pumps for B100. Anti-microbial products may be useful in preventing microbial growth in storage and fuel tanks.
GHG emissions	Influenced by the biomass feedstocks used to produce the biodiesel. RTFO verified biodiesel GHG emissions

	savings, relative to the fossil comparator, are typically around 86% (ranging from around 63% to 93% depending on the biogenic waste feedstocks used to produce biodiesel supplied at blends higher than B7 retail diesel). GHG emissions savings also vary depending on the blend of biodiesel, with higher blends giving rise to greater savings. Typical savings relative to retail diesel, are around 76-83% for 100% biodiesel, 20-22% for B30 and 12-13% for B20.
Air pollution emissions	NOx and PM emissions are equivalent to diesel. Irrespective of the fuel used, older plant and equipment require fitment of exhaust aftertreatment technology to achieve Stage V NRMM emissions standards.
Financial	Similar for B20/B30; higher for B100 due to costs of plant and equipment modifications as well as storage tanks.

Renewable Diesel (including HVO)

Production	Renewable diesel is a paraffinic fuel made from renewable sources that is chemically similar to conventional diesel. It is commonly referred to as a 'drop-in' fuel because it can be used without engine or fuel storage modifications. Hydrotreated vegetable oil (HVO), the most common type of renewable diesel, is produced by hydrotreating vegetable oils and fats. HVO can be produced from virgin vegetable oil, typically crude palm oil, and waste feedstocks such as used cooking oil and waste vegetable oils. HVO is typically supplied as 100% renewable fuel but can be blended with diesel or GTL (a fossil fuel derived paraffinic fuel).
Application in heavy-duty engines	Renewable diesel is required to conform to the European Standard EN15940. The majority of heavy-duty manufacturers approve the use of paraffinic renewable diesel (meeting the EN15940 standard) in their engines. Further information on engine approval can be found in Zemo's Renewable Fuels Guide Appendix but it is recommended that operators contact the manufacturer to confirm.
UK market - supply chain and deployment	Supply chains for renewable diesel are expanding in the UK, with increasing deployment in the NRMM sector. Renewable diesel supplied in the UK is produced from biogenic waste feedstocks. Examples of current applications include generators, cranes and reachstackers.
Operational considerations	Renewable diesel is classed as a 'drop-in' fuel, which means it can be substituted for conventional diesel with no impact on operational requirements for equipment or fuel storage infrastructure. Existing diesel storage tanks require cleaning prior to storing renewable diesel.
GHG emissions	Influenced by the biomass feedstocks used to produce the renewable diesel. RTFO verified HVO GHG emissions savings, relative to the fossil comparator, are typically around 88% (ranging from 81% to 96% and produced from biogenic waste feedstocks).

	Typical savings relative to retail diesel, are around 81-91% for 100% renewable diesel. GHG savings will be lower if renewable diesel is blended with fossil fuel.
Air pollution emissions	Cleaner burning than diesel, producing lower NOx and PM emissions. Irrespective of the fuel used, older plant and equipment require fitment of exhaust aftertreatment technology to achieve Stage V NRMM emissions standards.
Financial	More expensive than diesel, due to the higher price of renewable diesel.

Biopropane

Production	Biopropane, or bioLPG, is a renewable fuel that is chemically identical to conventional fossil fuel LPG. Biopropane is mainly produced as a co-product of the HVO production process. Feedstocks include energy crops and biogenic waste materials.
Application in heavy-duty engines	Biopropane can be used as a direct substitute to LPG and is classed as a 'drop-in' fuel.
UK market - supply chain and deployment	The UK biopropane market is currently small, with applications in the NRMM sector mainly focused on forklift trucks and gas engine generators (mobile and stand-by). Solid oxide fuel cell generators using biopropane have also been trialled in off-road applications.
Operational considerations	Bunkering of biopropane on site. Refuelling can be by a 'Mother and Daughter' system whereby a bulk tank is delivered to the site with systems to enable safe refuelling to smaller, machine-specific storage tanks. This enables the user to purchase at a wholesale LPG cost.
GHG emissions	Influenced by biomass feedstocks used to produce the biopropane. RTFO verified biopropane GHG emissions savings, relative to the fossil comparator, are typically around 86%. For energy crop feedstocks the savings are around 77% (excluding indirect land use change factor) and for biogenic waste feedstocks they range from around 69% to 96%. Typical savings relative to retail diesel, are around 57-67% for 100% biopropane.
Air pollution emissions	Lower NOx and PM than diesel.
Financial	Investment in new equipment and infrastructure is required if not already using LPG. Fuel duty rate for bio-propane is lower than diesel.

Biomethane

Production	Biomethane is the renewable equivalent of natural gas. Biomethane used in the transport sector is made from biogenic waste via the process of anaerobic digestion. Waste feedstocks include food waste, sewage sludge, agriculture residues and manure. Biomethane is typically compressed and distributed via the UK natural gas grid.
Application in heavy-duty engines	Biomethane is a 'drop-in' fuel, straight substitution for natural gas.
UK market - supply chain and deployment	Biomethane supply is expanding in the UK, with production focused on biogenic waste feedstocks. In the NRMM sector, biomethane can be used as a renewable fuel in gas powered generators and forklifts.
Operational considerations	On-site refuelling infrastructure includes compressed biomethane storage tank and dispensing equipment. This can be directly connected to the natural gas grid. In the UK, the RTFO allows producers to 'mass balance' biomethane supplied via the natural gas grid, such that the volume of biomethane injected into the grid matches the volumes of biomethane extracted.
GHG emissions	Influenced by the biomass feedstocks used to produce the biomethane. Biomethane produced from wet manure (livestock slurry) can be 'carbon negative' with savings exceeding 100%: this is because fugitive methane emissions are captured, thereby preventing them reaching the atmosphere and contributing to global warming. RTFO verified biomethane GHG emissions savings, relative to the fossil comparator, average around 88% (ranging from 67% to 179% for biogenic waste feedstocks). Typical savings relative to retail diesel, are around 81-125% for 100% compressed biomethane and 69-125% for 100% liquified biomethane.
Air pollution emissions	Lower NOx and PM than diesel.
Financial	Similar to diesel. Requires purchase of new biomethane generator, however biomethane has lower fuel duty rate than diesel giving rise to operational cost savings.

Future fuels

The table below shows some example advanced 'drop-in' biofuels, produced from a variety of waste-based biomass feedstocks that are expected to be available in the future. The estimated timeline for these renewable fuels coming to the UK market is also indicated. In the future, hydrotreatment plants will likely co-produce renewable diesel and sustainable aviation fuel.

Future fuel	Production	Year expected to enter UK market
Advanced biomethane via biosyngas (bioSNG)	Produced via the gasification of solid biogenic material such as waste wood.	2025
'Biomass-to-liquid' renewable diesel	Produced from the pyrolysis of agriculture and forestry wastes and residues.	2025
rDME (renewable dimethyl ether)	Produced through the gasification and chemical conversion of waste-based biomass feedstocks such as forest residues, municipal waste and sewage sludge. rDME is a low carbon liquid gas that can be blended by up to 20% with LPG and bio-propane without modifications to existing infrastructure.	2026

Low Carbon Hydrogen

Policy landscape

The UK Hydrogen Strategy was launched in August 2021 outlining the Government's ambitions for expanding the supply and usage of low carbon hydrogen across the UK economy. A key driver for the deployment of hydrogen is to reduce GHG emissions from a variety of sectors including transport. In 2023 the Government increased the ambition to have up to 10GW of low carbon hydrogen capacity by 2030. The UK Low Carbon Hydrogen Standard defines what constitutes 'low carbon hydrogen' up to the point of production and sets out the methodology for calculating the emissions. The RTFO is also supporting the deployment of renewable hydrogen in road transport and non-road mobile machinery, although to date, the volumes of renewable hydrogen verified under the RTFO are very small (less than 0.1% of renewable fuel supplied). Currently it remains uncertain whether the UK Government will class internal combustion engines using hydrogen as a zero tailpipe emissions technology for NRMM.

Production	Low carbon hydrogen can be produced from various production pathways and energy sources. Over the next five years the predominant pathways will include: – Electrolysis of water using renewable electricity. – Steam methane reformation using natural gas or biomethane with carbon capture and storage (CCS). – Biomass gasification with or without CCS. Once produced, hydrogen is typically stored in high pressure storage tanks and transported by tube trailer to the end users' hydrogen refuelling station as compressed hydrogen. In the future, low carbon hydrogen might be imported into the UK by ship, in the form of liquified hydrogen or as ammonia (requiring a cracking process to convert the ammonia back into hydrogen after reaching the UK). This will need to arrive at UK ports equipped with dedicated liquid hydrogen or ammonia storage facilities. Hydrogen can be produced on-site, for example via an electrolyser connected to a refuelling station. The electrolyser would need to be powered by renewable electricity for the hydrogen to be to be classed as 'low carbon'. If a direct connection is not possible, renewable

	electricity could be purchased using a power purchase agreement.
Application in heavy-duty engines	Hydrogen can be used to power hydrogen fuel cells (HFC) or internal combustion engines (H2ICE).
UK market - supply chain and deployment	The low carbon hydrogen market is in its infancy, with very limited commercially available supply chains and growing competition for supplies from other sectors. Large scale commercialisation is likely to materialise from 2030 onwards. The use of hydrogen in the NRMM sector is currently in the early stages, with H2ICE and HFC, pilot and demonstrator applications including forklift trucks, excavators, dump trucks, mixer truck and generators (including shore-to-ship applications). Several ports are looking at the opportunities for producing, supplying and using hydrogen. Some feasibility studies include the evaluation of the potential for hydrogen fuelled port cargo handling machinery. Hydrogen infrastructure deployment is more challenging than for other low carbon fuels in terms of: land availability, planning processes, grid connection, health and safety regulations, COMAH (Control of Major Accident Hazards) regulations restricting the capacity of hydrogen storage at depots, and limitations on tube trailer capacity for the delivery of compressed hydrogen.
Operational considerations	The storage and use of hydrogen requires stringent health and safety procedures and measures. The volume of hydrogen stored at a location will influence specific health and safety regulations that need to be adhered to.
GHG emissions	Influenced by the production pathway and energy source, plus the downstream supply chain, in particular method of storage and transportation. Production routes involving renewable energy (‘green’ hydrogen) result in the lowest GHG emissions. When hydrogen is produced using biomass feedstocks and linked with CCS, the GHG emissions can be negative. GHG emissions savings, relative to retail diesel (on an energy basis), are expected to be around 95% for an

	on-site electrolyser powered by wind turbines and around 60% for biomass gasification without CCS. Gasification plants with CCS could offer greater savings of around 150%. Currently, hydrogen produced by electrolysis powered by UK grid electricity, and hydrogen produced by steam methane reformation of natural gas, both have a higher carbon footprint than retail diesel (GHG emissions may be 20 to 50% higher). It's also worth noting that irrespective of the supply pathway, the hydrogen production process is energy intensive compared to electricity generation and the production of many renewable fuels.
Air pollution emissions	HFC produce only water vapor and warm air. H2ICE emit NOx emissions, lower than diesel.
Financial	Significantly higher - purchase of new HFC/H2ICE equipment, hydrogen storage and refuelling infrastructure, and cost of fuel. Economic viability depends on fleet size, shift duration, location, availability of hydrogen, infrastructure requirements and availability of subsidies or financial incentives.

Future Fuels

Low carbon methanol, ammonia and e-fuels (synthetic diesel) are identified as future 'hydrogen' fuels, however these are unlikely to be commercialised in the UK market until after 2030. Specific engine technology is required for methanol and ammonia; these are in the demonstration phase.

Electrification

Production	Electricity in the UK grid is generated from a mix of fossil and renewable energy sources. Renewable electricity can be produced from wind turbines or solar panels.
Application	Electricity can be used to power new equipment where products are available. Tethering is limited to certain machinery types and use cases.
UK market - supply chain and deployment	Renewable electricity can be produced on-site or purchased from the national grid using a power purchase agreement. The use of electric NRMM is currently in the early stages, with some equipment coming to market, including tethered electric cranes, battery-electric straddle carriers and battery-electric terminal tractors. Tethering and battery charging infrastructure deployment is not without challenges and ports are likely to require upgrades to the existing grid connection. This site-specific process is often costly and lengthy (ranging from 12 weeks to several years).
Operational considerations	Maintenance and operation of equipment with high voltage batteries requires stringent health and safety procedures and measures.
GHG emissions	Influenced by the primary energy sources used in electricity generation. In-use GHG emissions savings, relative to retail diesel (on an energy basis), are expected to be 100% for on-site renewable electricity and around 15% for grid electricity, based on the UK grid today. The savings for grid electricity are expected to increase as the grid decarbonises over time. For battery-electric NRMM, the life cycle GHG emissions savings will be lower than these values due to the higher embedded emissions from production (batteries have a high carbon intensity, both in terms of raw materials and manufacture).
Air pollution emissions	None at point of use.

Financial	Significantly higher - purchase of new electric equipment and infrastructure upgrades. Economic viability depends on fleet size, shift duration and availability of subsidies or financial incentives. Tethering typically offers lower capital and operational costs compared to battery-electric.

Initiatives supporting clean & sustainable low carbon fuels adoption

Renewable Fuels Assurance Scheme

The Renewable Fuels Assurance Scheme (RFAS) is an independent initiative managed by Zemo Partnership. The Scheme verifies claims made by companies supplying renewable fuels to heavy-duty vehicle and equipment operators regarding their product's GHG emissions savings performance and provenance of raw material feedstocks. The RFAS encompasses the complete renewable fuel supply chain from feedstock cultivation or waste raw material collection, production and distribution of the final product to the customer.

The RFAS works alongside the Government's RTFO providing a mechanism for guaranteeing that fleet operators are purchasing bulk supplies of sustainable low carbon fuels. Transport sectors covered by the scheme are road vehicle and heavy duty off-highway, notably non-road mobile machinery used on construction sites and ports. Example renewable fuel types that can be approved include biodiesel, renewable diesel including HVO, biomethane, renewable hydrogen, various development fuels and blends of renewable fuels.

Approved Renewable Fuel Suppliers issue their customers with Renewable Fuel Declarations for batches of renewable fuels that have been sold each quarter. The declaration identifies the types and volumes of renewable fuel purchased, the GHG emissions intensity and savings, and the types and origin of the of raw material feedstocks. The declaration is specific to each customer and is non-transferable, to ensure that the chain of custody is unbroken and the information presented is valid.

To date, forty renewable fuel suppliers are approved under the Renewable Fuels Assurance Scheme. A list of approved suppliers can be found on the RFAS webpage via the QR code or the link below. Zemo have also produced a 'Guide for Fleet Operators' and accompanying calculator to help operators to estimate the Well-to-Wheel GHG emissions of the renewable fuel purchased.

Further information: https://www.zemo.org.uk/RFAS

NRMM Retrofit Accreditation Scheme

The Energy Saving Trust independently certifies NRMM NOx and PM emissions reduction systems that can be retrofitted to NRMM. This allows them to be used in areas which experience air quality challenges. Gaining NRMM certification offers the assurance that retrofit equipment meets the requirements of local authority air quality policy or the environmental requirements of certain development projects. The latest exhaust emissions standards for NRMM powered by diesel and gas engines are Stage V limits. Examples of NRMM with retrofit technology certification include excavators, bulldozers, generators, forklifts, mobile cranes. At present this is for equipment predominantly used on construction sites.

Further information regarding approved technologies - Non-road mobile machinery certification - Energy Saving Trust

Appendix

Examples of low carbon fuel deployment and electrification in UK Ports:

Port	Energy source	Deployment in NRMM equipment
Shoreham Port	HVO	HVO bulk storage at the terminal for use in forklifts, cranes and marine vessels. GHG savings quoted as over 600t CO_2 annually.
Southampton Port	HVO	HVO used to eliminate fossil diesel from it's operations with estimated GHG savings of around 14,000t of CO_2 annually. Includes use in forklift trucks, straddle carriers, and generators for refrigeration units.
Port of Immingham	HVO	HVO used in 4 Konecranes reachstackers and 3 Liebherr 420 cranes.
Forth Ports	HVO	HVO used in part of its plant technology and vehicles, including tug tractor units and reachstackers.
Port of Dover	HVO	HVO used in 3 Liebherr mobile harbour cranes (LHM 280, and 550).
Peel Ports (multiple locations)	HVO and electricity	Many assets using HVO with GHG savings of over 11,800t CO_2 annually. Electric forklifts being trialled. Electric cranes at Liverpool2 terminal. All vehicles, plant equipment, forklifts, tug masters and ancillary equipment at Heysham are operating on HVO or electricity.
Port of Felixstowe	Electricity	6 Konecranes electric rubber-tyred gantry cranes, plus some retrofitting of diesel gantry cranes with electric motors. Fleet of 148 battery-powered internal tractor units. New port cars and vans are electric. 2000 solar panels have been installed on site.
London Gateway	Electricity	All-electric new fourth berth with 8 Kalmar electric straddle carriers, providing 4 hours of operation with 45 minutes charging time. Estimated GHG emissions of 54% compared with non-electric models. Also, fully electric terminal tractor, electric quay cranes and 4 Konecranes automated stacking cranes.
Port of Hull	Electricity	6 Linde electric forklift trucks operating at their on-site retail warehouse, adjacent to the Humber Container Terminal.

Examples of UK Ports looking at the opportunities for producing, supplying and using hydrogen:

Port	**Energy source**	**Projects and plans**
Port of Immingham	Hydrogen	Plans to build a green hydrogen production facility using imported ammonia.
Shoreham Port	Hydrogen	Plans to establish a green hydrogen energy hub, incorporating a 20 MW electrolysis plant using renewable energy. Hydrogen to be used in port cranes and forklifts, vessels, and local fuel cell buses, HGVs and waste collection vehicles.
Orkney Islands	Hydrogen	Hydrogen production from excess tidal and wind energy is stored and transported to the Orkney mainland where it can be used in powering harbour and ferry operations.
Port of Tilbury	Hydrogen	Plans for a small scale demonstrator project to produce green hydrogen for decarbonising port equipment, and an initial study into a 10 MW green hydrogen plant, with a view to scaling up to 100 MW over a 10 year period. Hydrogen would be used for port infrastructure and operations, and surrounding industry.
Port of Leith	Hydrogen	Plans to trial a hydrogen generator to power tug vessels while at berth. Green hydrogen will be produced using wastewater from a water treatment works close to the Port.
Teesside Port	Hydrogen	Plans to use hydrogen in their fleet of vehicles and for decarbonising port operations.
Portsmouth	Hydrogen	Plans for 35 kW electrolyser producing hydrogen using electricity from the port’s solar array. Hydrogen to be used to power an outboard motor (H2ICE) on a purpose built boat for towing mooring lines, working harbour patrols and undertaking conservancy work.
Milford Haven	Hydrogen	Project exploring the potential for hydrogen in a local energy system (including heat, electricity and transport) for Milford Haven, Pembroke and Pembroke Dock. Electrolyser aims to supply fuel cell vehicles, including port vehicles.

HVO and other renewable diesels are ‘drop-in’ fuels and can often be used in new and existing diesel equipment. Some manufacturers are promoting the benefits of using HVO in their products in their brochures or on their websites, e.g. Kalmar Eco reachstackers, Konecranes lift trucks. Hyster offer an HVO aftermarket kit (replacing FKM seals with nitrile rubber seals) for their big trucks, empty container handlers, and reach stackers.

Examples of electric and hydrogen NRMM equipment:

Technology	NRMM product type	Product name
Battery-electric	Forklift, teletruk	JCB 30-19E, 30-22E and 35-22E
Battery-electric	Telehandler	JCB 525-60E
Battery-electric	Reachstacker	Kalmar ERG450-700
Battery-electric	Top pick container handler	Kalmer ECG90-110
Battery-electric	Forklift	Hyser J10-18XD
Hydrogen fuel cell	Reachstacker	Hyster (trial stage)
Hydrogen fuel cell	Container handler	Hyster (trial stage)
Hydrogen fuel cell	Rubber-tyred gantry crane	MITSUI-Paceco H2-ZE Transtainer
Hydrogen fuel cell	Generator	EODev GEH2
Hydrogen fuel cell	Generator	PowiDian MobHylPower M110
Hydrogen fuel cell	Generator	Hitachi HyFlexTM (demo stage)