INFORMATION MEMORANDUM

presented by

Alliance for Clean Transportation

Comprehensive Emission Aftertreatment Solutions

Stax Corporation (USA)
T.F. Hudgins Corporation (USA)
HJS Emission Technology (Germany)

concerning

Emission Reduction Technologies in Ports Logistics

Getting to Zero

Electric Vehicles, Equipment, and Infrastructure Deployment for Aviation, Marine Port, Freight, and other Zero-Emission Specialized Equipment

October 15, 2024

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Chapter 1

Executive Summary

Clean transportation is a politico-economic imperative

Driven by new efforts to reduce greenhouse gas (GHG) emissions and air pollution, the development of emerging technologies will play an increasing role in the future of transportation and possibly other sectors of the economy. Some of these technologies may replace internal combustion engines in some applications, but the availability and cost framework of this alternative has not been adequately clarified today.

This information memorandum refers to the goals and requirements associated with achieving zero emissions. It describes and presents the technical possibilities of the combustion engine to meet these requirements with the help of exhaust aftertreatment devices. The authors explain and make various suggestions on how an immediate reduction of air pollution can be achieved with the latest technical retrofit procedures.

The authors emphasize and substantiate that internal combustion engines, both gasoline and diesel, will continue to be the most important powering source for many decades into the future to ensure continued progress on transportation and meeting society's greatest challenges, achieving cleaner air and reducing GHG emissions, as other emerging technologies are yet to reach commercial availability at scale.

Retrofitting the combustion engines and mobile diesel-powered equipment in operation would be a convincing way for stakeholders to save time and money while actively contributing to cleaner air and human health. Moreover, diesel-powered engines run on eFuels would lead to even more significant time and cost savings compared to new investments if the use of existing aggregates would be maintained.

This paper provides information about state-of-the-art technical solutions to air pollution problems. It shows, how they could be solved, underpinned with system and functional descriptions for the modernization of vehicles and equipment, supplemented by best practice examples as they could be applied in the logistics sector.

The authors point out that the advantages of retrofit technologies are:

- Available, highly effective, cost-efficient, VERT approved
- Reduction of pollutant emissions, immediately, here, and now
- More economical investment choice than purchasing new vehicles
- Suitable for increasing energy efficiency and cost savings
- Allows for current inventory of vehicles to operate to end of life
- Opportunity for expanded use of renewable eFuels
- Can be used for all diesel-powered vehicles and equipment

Diesel retrofit technologies are available, efficient, field-tested and VERT approved, economical - and ready for use without delay.

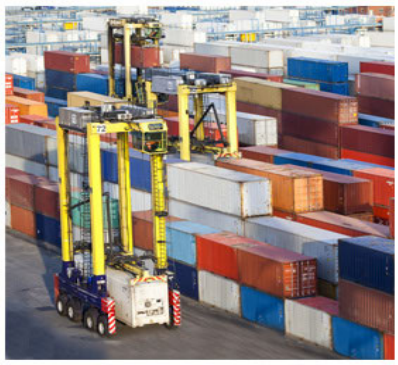
Chapter 2

Purpose and Objectives

On the way to Zero Emissions





- The Alliance for Clean Transportation, a well-established consortium of three companies two based in the U.S. and one in Germany, aims to provide information, on what appropriate measures currently exist to address the highly dangerous air pollution and climate change threats posed by transportation in our metropolitan areas and in supply centers such as port logistics.
- This briefing memorandum summarizes possible options which could be taken to remedy the problem situation as quickly as possible. The primary focus is to consider **proposals to reduce pollutant emissions** from internal combustion engines, primarily on modernization solutions for existing, predominantly diesel-powered vehicles and aggregates, whose retrofitting with state-of-the art exhaust gas aftertreatment technology offers best options, supplemented with information on with a wide range of **best practice examples** of successful implementation.
- After reviewing and examining the use cases listed in the Request for Information catalog, we see **promising opportunities to propose useful techno-economic solutions** for a large number of transportation vehicles and aggregates used in the port.

The ZERO emission powertrain is the ultimate goal![1]

[1] Menne Christoph, Independent Thermal Management for high NO_X conversion especially in Urban Operation, 6th International Engine Congress Baden-Baden, HJS Emission Technology GmbH & Co. KG, 2019., p 8.

Chapter 3

Problem and Challenges

Greenhouse gas emissions and air pollution

- Climate change is a global challenge that requires global solutions. World-wide partnerships will therefore have to play a key role in the transition to a green economy. Clean air and clean transport are two sides of the same coin.
- Several options are available to reduce greenhouse gas and air pollution. This includes battery electric vehicles, fuel cells, plug-in hybrids, efficient combustion engines and a circular economy.
- Excluding the use of combustion engines would be counterproductive and unnecessary. This is not only potentially highly detrimental to industry, to its employees and to consumers, but would also be counterproductive to reducing emissions.
- Eliminating affordable low-carbon options for those consumers and businesses for which electrification does not provide the necessary utility or cost effectiveness, will leave older, higher-emitting vehicles on the road.
- A prohibition is also not necessary as climate-neutral internal combustion with renewable and low carbon fuels is viable and can cut emissions not only from new vehicles but also from the existing fleet. The SCR technology can reduce emissions during the transition period and can help specific use cases where electric powertrains are not the optimal solution.[2]
- The transportation sector plays a key role in the society, connecting people and businesses in the economy. It generates considerable added value in terms of GDP and employment. Trade, healthcare, education, political participation, or cultural interaction depend on reliable and affordable transport systems.
- Air pollution, especially in urban areas, also poses the greatest environmental risk to health. Particulate matter (PM), nitrogen oxides (NO_x), ozone and other harmful substances lead to premature deaths, an increase in cardiovascular disease, respiratory disease, and cancer.
- The US and the EU regulate emissions of air pollution from vehicles through different directives and guidelines, stimulating a motivation for the industry to develop new and most effective air cleaning technologies.
- The transportation sector is challenged to act responsibly and quickly to address the problems. The pursuit for clean air must be intensified and implemented immediately and decisively at the international level. Therefore, it is imperative to invest in sustainable solutions that will make us emission-free in the future now. Because the length of time until then also plays an important role.

Clean air and clean transportation are two sides of the same coin. The formation of greenhouse gases must be curbed immediately. And that has a lot to do with clean air.

[2] Excerpt: European Association of Automotive Suppliers (CLEPA), Brussels, February 2021

Chapter 4

Powering the Future

Outlook

- Tackling the multiple challenges of reducing greenhouse gas emissions (GHG), implementing adaptation and mitigation measures requires many solutions. Diesel is one of those solutions.[3] Globally, one out of every two economic sectors depend on diesel power. Trucks, trains, buses, marine workboats, agricultural, forestry, mining and construction equipment rely almost exclusively on diesel.
- The variety of available solutions for clean diesel engines continues to grow. For example, fueling the existing vehicle fleet with renewable, bio-based fuels or new E-fuels is promising. Hydrogen as a fuel for internal combustion engines is also on the rise, from use in passenger cars to transporting heavy trucks to applications in the industrial sector. And there are also strong improvements in gasoline engines.
- Heavy-duty battery-electric trucks (BET) may offer tremendous potential for greenhouse gas emission reduction in transport. However, owing to limited electric range and high acquisition costs, their current feasibility in logistics is not fully developed.[4] Electric Vehicles (EV's) need time in the market to gain reliability experience. Safety issues of using and maintaining batteries need to be better understood along with battery life. Safety issues needs to be understood and adopted.
- On the road to zero emissions and before commercial vehicles and other equipment can be electrified across the board, a number of important infrastructure and technological challenges still need to be overcome.
- Fueled by new efforts to reduce greenhouse gas (GHG) emissions, the development of emerging technologies such as batteries and fuel cells will play an increasing role in the future in the transportation and possibly other sectors of the economy.
- Some of these emerging technologies may replace diesel in some applications, while diesel will continue to be the dominant technology for the foreseeable future in others. Green hydrogen is being touted as a solution to Europe's net-zero ambitions, but the infrastructure is still in its infancy.
- Therefore, additional investments in innovative processes, infrastructure and new equipment are needed in this respect. Clarifying the economic viability of the processes and measures must also not be ignored.

All of this takes time.
And clean air and climate protection do not have that time.
Immediate action is needed.

[3] https://www.dieselforum.org/diesel-powers-the-future/diesel-powers-the-future

[4] Fraunhofer Institute for Systems and Innovation Research ISI, Delivery Traffic with Battery Trucks: Feasibility 2021- Case Study REWE Group, Northeast Region of Germany, Core Results, p. 5, Key Findings, para. 1, Karlsruhe, November 2021.

Chapter 5

Advanced Diesel Technology

A sustainable solution

- The internal combustion engine, and especially the diesel engine, is characterized by the fact that it is very powerful and autonomous at the same time. Modern diesel engine technology remains a reliable and energy-efficient source of power and propulsion. No other fuel or technology can match the combination of energy efficiency, workability, reliability, durability, economy, and environmental friendliness that diesel offers in all parts of the world.
- This technology will continue to play an important role for some time to come. Higher pressure and temperature in modern diesel combustion allows better fuel efficiency and reduces CO_2 at the cost of increased NOx and particle emissions. In state-of-the-art diesel engines, this trade-off is addressed via active exhaust treatment systems, catalytic converters, SCR technology and particulate filters.
- Thus, the most recent emission regulation standards can be met with available technology. Recent examples have shown further potential to reduce pollutant emissions of Diesel engines, achieving NOx emission levels 10 times lower than the limits set to be applicable as of 2020[5]

"Whatever form the future takes, we can be 110 percent sure that Near Zero Emissions, suitability for hybridization and electrification and the ability to utilize more advanced renewable biofuels are all key features of advanced diesel technology today and will only grow in importance for tomorrow."[6]

- The economic, fuel-efficient, high torque engines powers many of the world's commercial vans, trucks, buses, and non-road vehicles, marine and rail. Diesel-powered vehicles are indispensable as a highly useful tool, especially for transportation of goods. Diesel is the technology of choice bringing about immediate effective pollutant reduction from exhaust gas.
- Compared to gasoline engines, diesel engines score with significantly lower fuel consumption and lower CO_2 emissions. The auto-ignition process makes much better use of the energy in the fuel. An advanced diesel with a tendency to higher mileage ensures low consumption. It is no coincidence that the diesel unit dominates the fleets of commercial operators in professional logistics.
- Due to the gradual fleet-renewal rate or **upgrading of older diesel engines (retrofit)** and mobile diesel-powered equipment, diesel is a convincing way for investors to save time and money while actively contributing to clean air and human health.
- From government sources to international consulting firms, authorities agree that internal combustion engines - both gasoline and diesel - will continue to be important for many decades into the future to ensure continued progress on meeting society's greatest challenges - **achieving cleaner air and reducing GHG emissions** - as other emerging technologies are yet to reach commercial availability at scale and with still unknown impacts from the global pandemic.

[5] Robert Bosch GmbH reportedly measured 13 (!) mg NOx per kilometer under real driving conditions. Since 2017, European legislation has required that new passenger car models tested according to an RDE-compliant mix of urban, extra-urban, and free-way cycles emit no more than 168 milligrams of NOx per kilometer. As of 2020, this limit will be cut to 120 milligrams.

[6] https://www.dieselforum.org/about-clean-diesel

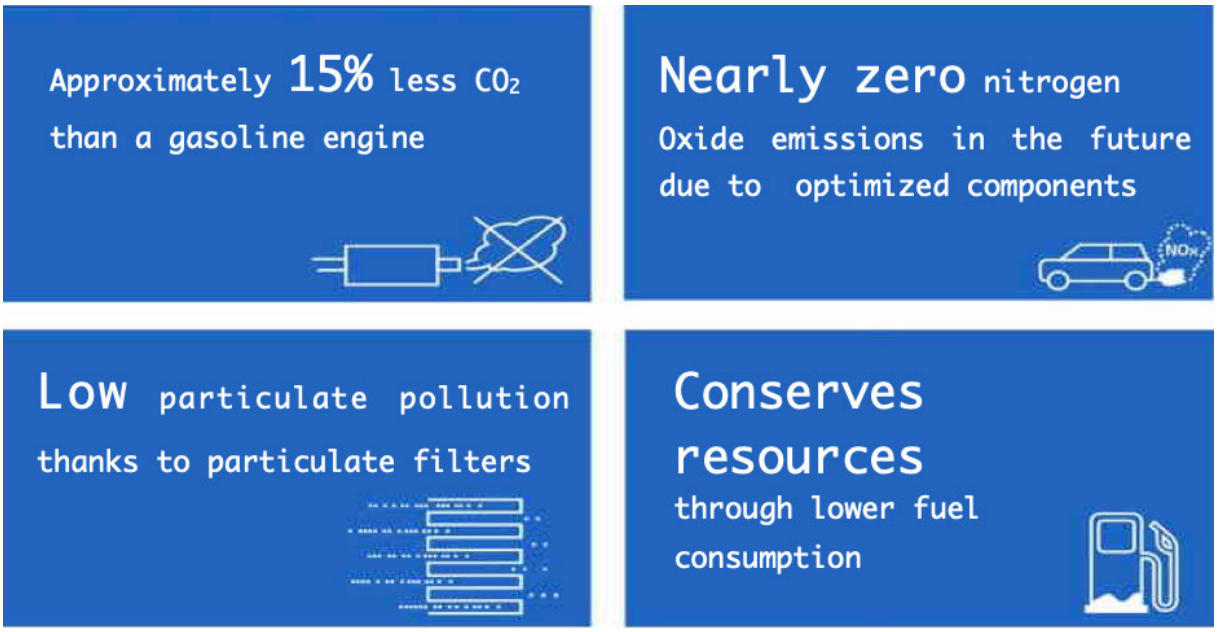


Figure 1: Main benefits of diesel engines

- No other engine technology achieves the unique combination of energy efficiency, performance, reliability, and durability. A sizable fleet of diesel equipment manufactured over two to three decades ago is still in operation in the US or in the EU.

- **Diesel is truly the workhorse in the economy with engines often lasting hundreds of thousands of miles or running for hundreds of thousands of hours.**

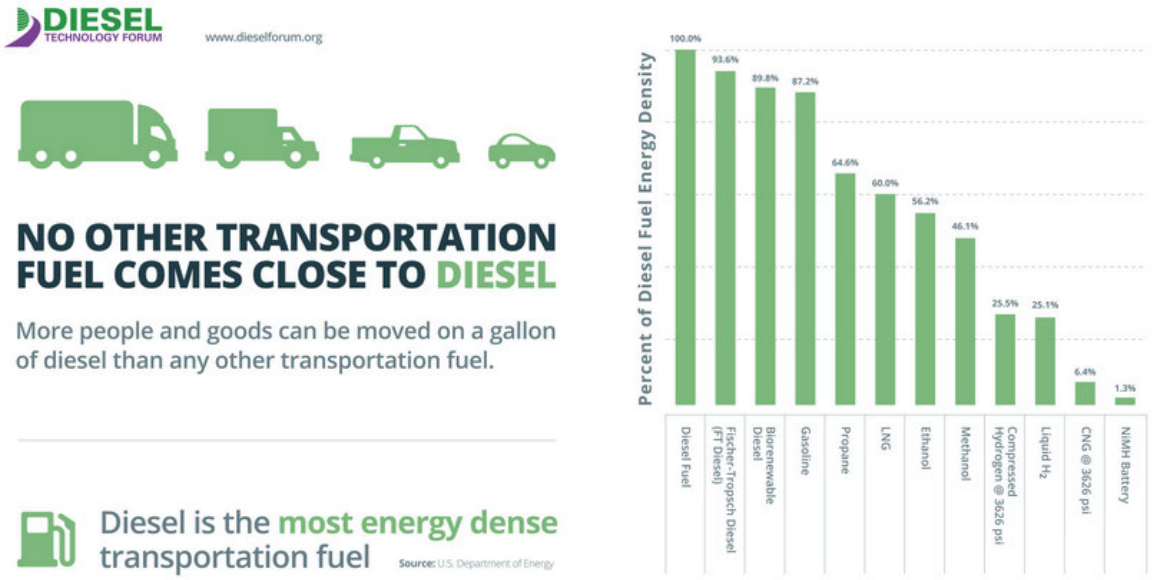


Figure 2: Effectiveness of Diesel

- Diesel has always been a technology of continuous improvement, and this initiative sets the pace for the next generation of advanced diesel technology. Diesel emission control systems must run the performance under real driving cycles, the ideal bridging technology until zero emission technology.[7]
- The diesel engine is the technology of choice, providing an immediately effective reduction of pollutants in the exhaust gas. Retrofitting older diesel engines is a cost-saving way to achieve even the highest emission standards with immediate effect.
- Investing in diesel retrofits provides an immediate reduction in pollution. It provides a cost savings in extending the lifecycle of diesel-powered equipment compared to the high costs of acquiring electric vehicles and initial infrastructure costs. It allows PANYNJ to benefit from using existing equipment assets and subsequently phase in electric vehicles over time.
- In ports, air quality is rapidly improving thanks to the accelerated turnover to new clean diesel engines deployed in many cargo handling applications, along with retrofit activities to install emission control technologies on older diesel engines.[8]
- The carbon intensity of the fuel or the energy carrier is decisive for wheel-to-wheel CO_2 emissions, not the vehicle technology. An electrical vehicle (EV) running on **coal-based electricity** will generate more CO_2 emissions than a conventional internal combustion engine (ICE) vehicle on fossil fuel. CO_2 assessments should be carried out on a wheel-to-wheel basis, even better on life-cycle assessment (LCA) basis, not solely focusing on tailpipe CO_2 emissions.
- Current estimates of global warming illustrate that gasoline engines are inferior to diesel in the cases of CO2 emissions and fuel efficiency. What's more, the latest diesel engines are the cleanest ever, of nitrogen oxides (NO_X) and particulate matter from exhaust gases.
- While the push towards zero-emission, battery electric vehicles (BEVs) dominate the headlines, the diesel engine remains a major source of power. It powers (almost exclusively) our military, construction, and agricultural machinery, as well as the Class 8 trucks that transport our goods, rail applications and the cargo ships that connect the global economy.

Diesel technology is expected to be the preferred propulsion technology for the next ten to fifteen years, especially for class 8 heavy-duty trucks, marine, rail, gensets and other off-road equipment.

[7] https://epa.gov/cleandiesel/verification/verif-list.htm and www.arb.ca.gov/diesel/verdev/vt/cvt.htm

[8] Diesel Technology Forum, New Generation of Diesel Power in Commercial Trucks and Buses Delivering Major Climate and Clean Air Benefits, Washington, DC, July 16, 2019.

Chapter 6

Booster for the Combustion Engine

Bio- or Synthetic Fuels

- **E-Fuels** are being traded as a climate-friendly fuel alternative to gasoline, diesel and methane. This is because if these synthetic fuels are produced using renewable energies, they are climate-neutral in balance sheet terms. In theory, any fuel-powered vehicle can be fully or partially fueled with E-Fuels. Vehicles powered with E-Fuels will contribute to an overall more climate-friendly mobility sector.
- Bio or synthetic fuels will be CO_2 neutral. E-Fuels are a solution for all vehicles and means of transport. E-Fuels are synthetic fuels produced regeneratively from water and carbon dioxide (CO_2). The fuel influences the emission behavior of engines. By using biogenic fuels or natural gas, pollutant and CO_2 emissions can be significantly reduced - all the way to CO_2 neutrality.
- Low-CO_2 fuels can gradually replace fossil fuels. They make climate neutrality possible for applications where there are no realistic alternatives, such as aviation, shipping, and parts of the heavy-duty transport sector.
- E-Fuels are a solution for all vehicles and means of transport and may be indispensable in the future. Only they promise the high energy density needed, for example, in shipping, aviation and heavy-duty logistics. Battery-electric drives will probably not be able to achieve this in a similar form.
- Retrofits of older diesel engines and/or mobile diesel-powered equipment would be a convincing way for investors to save time and money while actively contributing to clean air and human health. Diesel powered engines that run on eFuels would lead to significant time and cost savings compared to new investments if the use of existing aggregates is maintained.

Two advantages are obvious

In principle, the existing diesel engines, equipped with the latest exhaust technology, can continue to be used and operated in an unchanged, highly environmentally friendly manner within the framework of the existing service station and service network.

Chapter 7

Retrofit for Getting close-to Zero

The way forward to clean air

- Retrofit technology has seen significant advances recently. Fleet renewal, and the replacement of older equipment and vehicles that meet or exceed the highest emission standards takes an average of more than 10 years. Air pollution needs a solution today. Time is of the essence!
- Retrofit technology includes filters, catalytic converters, and ammonia exhaust aftertreatment that target various pollutants in the exhaust, including carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM) and nitrogen oxides (NOx), bringing in-service units to a **comparable level of technology as new vehicles.**
- Retrofitting of medium-duty vehicles, heavy trucks, buses, and in off-road applications of various types therefore holds great potential for rapid and cost-effective reduction of pollutant loads. Given their nature, type and age, the cost-benefit ratio is good to very good.
- Retrofit is more up to date than ever, under normal conditions, fleet renewal, the replacement of older equipment and vehicles that meet or exceed highest emission standards, takes on average more than 10 years. Air pollution needs a solution today. Time is of the essence!

Retrofit Effectiveness

- ➢ Immediate reduction of pollutant emissions at source
- ➢ Upgrading to the highest available emission standard with utilization of SCR
- ➢ Field tested, advanced, available, affordable, time saving
- ➢ Cost-effective alternative to buying a new equipment
- ➢ Role model in health and environmental protection
- ➢ Helps immediately and is more up to date than ever.

Clean Air and Covid 19

- Long-term exposure to air pollution is associated with a higher risk of developing Covid-19, according to a new study led by the Barcelona Institute of Global Health. For the total study population, an association was found between higher exposure to nitrogen oxide (NO2) and particulate matter and Covid-19 symptoms, particularly for severe cases that ended in the hospital or in intensive care.[9]

[9] Air Quality News, United Kingdom, November 24th 2021
https://airqualitynews.com/2021/11/25/air-pollution-exposure-associated-with-higher-risk-of-developing-covid-19/

- Every single disease that is non-communicable is impacted by air pollution. It is not only involved in worsening diseases but in causing them, and new diseases, that wouldn't otherwise occur are happening because of air pollution.[10]

Chapter 8
Lifetime Extension and Economic Efficiency
Illustrated by the example of City buses in London[11]

Investing in clean buses delivers the best value for money

Retrofits for buses are proven to deliver Euro VI emission performance and are reliable with direct monitoring already in place. According to the study in London the bus options of retrofit and scrappage allowance offer much better value for money than a diesel car scrappages scheme or grants for electric cars.

Real world testing of Euro VI diesel buses demonstrates a 95% reduction in[12] NOx emissions compared with Euro V2. Currently a journey by diesel car, even a Euro 6 one, emits 10 times the per passenger NOx (383mg NOx/km) of a comparable journey by Euro VI bus (40mg NOx/km). The NOx emissions from a Euro VI bus passenger are even lower than a Euro 4 petrol car passenger (43mg NOx/km).

Investing in clean buses delivers the best value for money

Retrofits for buses are proven to deliver Euro VI emission performance and are reliable with direct monitoring already in place. Few retrofits exist for cars, they are unproven in the real world and very difficult to monitor in service. And if a scrappage scheme is justified for diesel cars the case is even more compelling for diesel buses.

Financial support for bus retrofitting provides more than 15 times as much value as scrappage allowances for diesel cars to convert to Euro 6 or electric, and 11 times as much value from a bus scrappage scheme compared with diesel car scrappage. The table below shows how much it would cost the Treasury to save 1kg of NOx per annum from different policies. The bus options of retrofit and scrappage allowance offer much better value for money than a diesel car scrappage scheme or grants for electric cars.

[10] Sir Stephen Holgate, the health effects of fine particulate air pollution, BMJ 2019; 367 doi: https://doi.org/10.1136/bmj.l6609 (Published 27 November 2019) Cite this as: BMJ 2019; 367: l6609

[11] Begg, David, Improving Air Quality in Towns and Cities. *Why buses are an integral part of the solution,* London, 27 April 2018

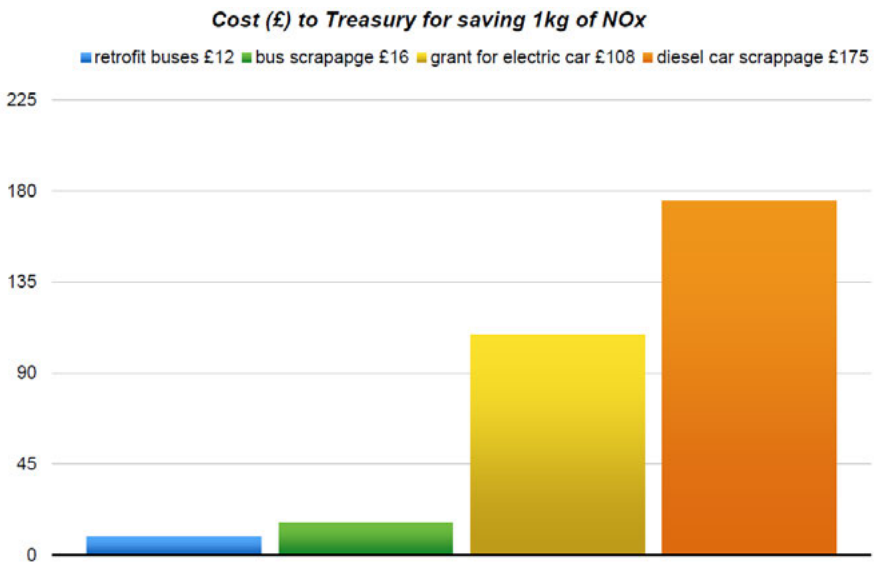


Figure 3::
Cost (£) to Treasury for saving 1kg of NOx

Assumptions: Retrofit costs £17,000 and lasts 5 years the cost is £12 kg of NOx saved. Scrapping a Euro III bus and replacing with Euro VI saves 600kg NOx per year. If the Euro III bus is 13 years old and has two-year life expectancy its book value would be around £20,000. I'm assuming it was purchased for around £150,000 in 2004 which means it depreciates at £10,000 p.a. over its 15-year life span. Assume the bus scrappage allowance is equal to book value cost per kg of NOx saved = £10,000/600 = £16. Grant for electrics car is £4,500 and has a 10-year life at a cost of £108/kg saved. If a Euro 3 diesel car is scrapped at £2000 and replaced with a new Euro 6 model and lasts 10 years the cost is £175/kg.

"So, the cost to the Treasury in terms of NOx saved is 15 times more expensive for diesel car scrappage than retrofitting buses, and 11 times more expensive than a bus scrappage scheme. The bus options offer much better value for money. "[13]

Replacing non-compliant buses

Whilst the aspiration to move from diesel to electric/hydrogen is widely shared, it is not logistically possible to replace this number of vehicles within such a short time frame. Even if it were logistically possible it couldn't be done without severe adverse consequences for city economies and their environment.

In the immediate term, Euro VI buses will deliver the seismic reduction in NOx and other harmful emissions that is required. This can be achieved by investing in new vehicles or retrofitting existing vehicles to Euro VI standard. The chart below shows the cost implications of replacing a vehicle.

[13] Begg, David, Improving Air Quality in Towns and Cities. *Why buses are an integral part of the solution,* London, 27 April 2018

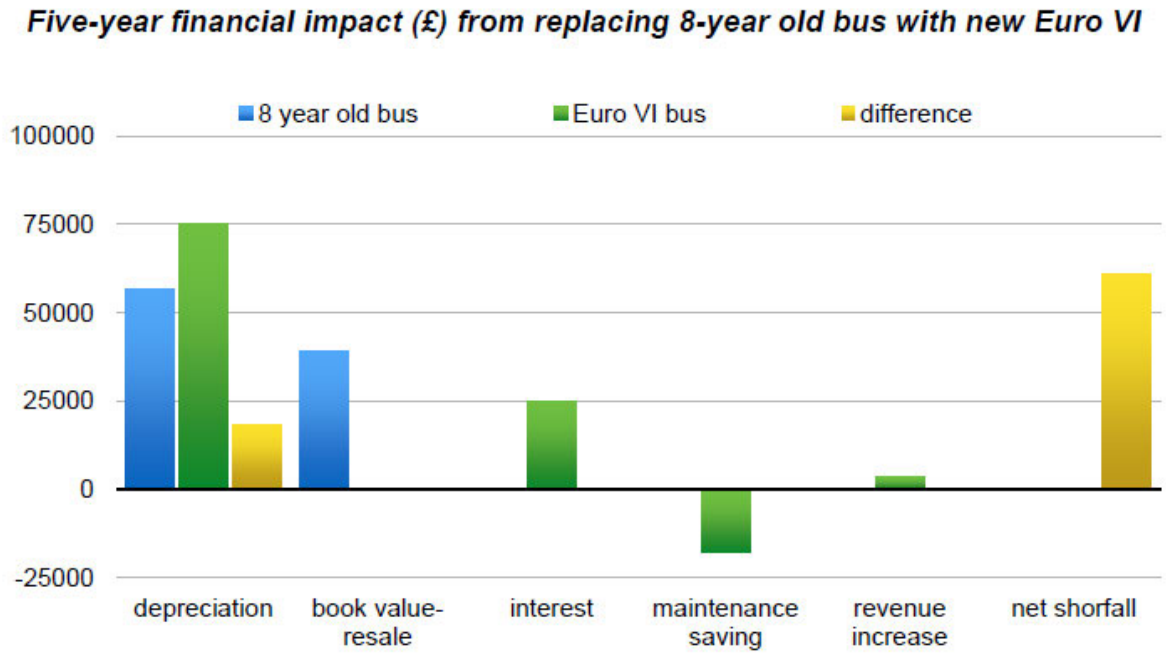


Figure 4:
Financial impacts of replacing buses

HJS Model Calculations

Upgraded Urban Truck NOx Emissions per year

RDE NO_x emissions	1 g/bhp/hour
Power	200 bhp
Load cycle	60 %
NOx emissions per hour	120g
SCR 90 % NO_x reduction under RDE conditions	**108g**
Average operation time p.a. 250 days x 8 hours	2,000 hours

NO_x emissions reduction per year 108g NOx/hour x 2,000 hours/year
216,000 g/year ≙ 0,22 tons/year

Upgraded City Bus NOx Emissions per year

RDE NO_x emissions	2 g/bhp/hour
Power	250 bhp
Load cycle	60 %
NO_x emissions per hour	300 g
SCR NO_x 90%reduction under RDE conditions	**270g**
Average operating time per year	3,000 h

NO_x emissions reduction per year 270g NOx/hour x 3,000 hours/year
810,000 g/year ≙ 0,81 tons/year
Investment SCRT System: $ 20,000

Comparison with New Electric City Bus per year

RDE NO_x emissions	0 g/bhp/hour
Power	250 bhp
NO_x 100% reduction vs. Diesel City bus	**300g**
Average operating time per year	3,000 hours

NO_x emissions reduction per year 300g NOx/hour x 3,000 hours/year
900,000 g/year ≙ 0,9 tons/year
Investment new electric bus: $ 650,000

Conclusion

33 existing public transport diesel buses can be upgraded for the amount of money spent on 1 single electric bus only.
NO_x emission reduction is covering 33 diesel buses coming up to 27 tons NO_x in total per year.[14]

[14] Further considerations on comparison with diesel buses: Improving-Air-Quality-in-Towns-and-Cities- PROF-DAVID-BEGG, London, 22nd April 2017; David *Begg*, Chief Executive, Transport Times. *London*, Transportation/Trucking/Railroad. EAMS Group, London, United Kingdom

Chapter 9

Remote Monitoring

Service and care

Remote Monitoring of Diesel Equipment to Ensure Optimum Performance of Diesel Particulate Reduction Strategies.

- The HJS Aftertreatment Control Unit (ACU) supplies the Telematics System with all relevant system data required for transmission via the Telematics Unit. HJS will provide a cloud-based interface for data storage and presentation.
- TFH provides customizable, flexible configuration options for data collection, data analysis and visualization, and expert support.
- Remote monitoring of diesel equipment will provide real-time insight into equipment performance and operational efficiency of diesel particulate reduction strategies deployed on Port Authority equipment. This and integration of The HJS Aftertreatment Control Unit (ACU) and the Telematics System delivers a best-in-class level of reliability.
- The ability to react quickly to performance degradations or malfunctions will provide the Port Authority with the confidence needed they are meeting the EPA emissions requirements in a consistent manner.

The TFH remote monitoring solution consists of these components:

1. **Cloud Services**
    - **a.** Connected to engine diagnostic data, diesel particulate filter control, made available to the cloud through Wi-Fi and internet service provider
2. **Information Factory**
    - **a.** Data Ingestion Module
        - **i.** Communications confirmation, data quality, anomaly detection
        - **ii.** Forms, schedules, inspections
    - **b.** Data Output logistic
        - **i.** Connecting to Visualization and Reporting engine
        - **ii.** Interactive input and output from end user
    - **c.** Alerts, Notification and Escalation Procedures
        - **i.** 24x7 procedures
3. **Analytics and Custom Soft Sensors**
        - i. Threshold violations
        - ii. Key Performance Indicators (KPI's)
        - iii. Trending
        - iv. Predictive Maintenance

4. **Infrastructure Data**

   a. Data historization

   b. Visualization and reporting

   c. Electronic logging for maintenance and inspections

   d. Forms input

   e. Operating and maintenance manuals

   f. HJS will provide a cloud-based interface for data storage and presentation.

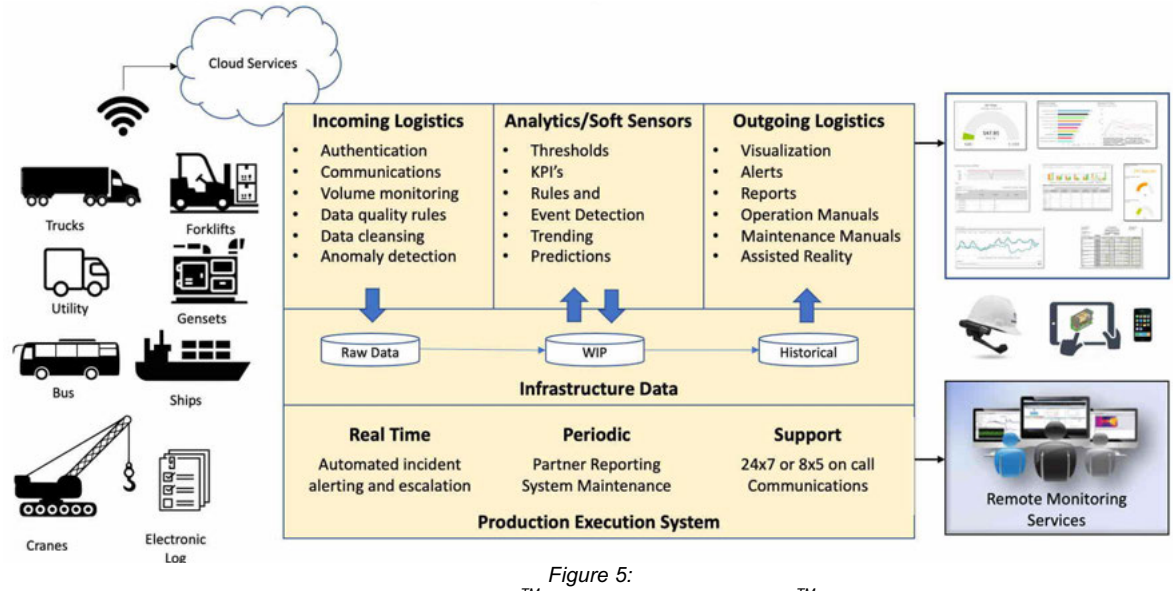


Figure 5:
Emissioninsight ™ & The Information Factory ™

Machine ID, Time/date, and NOx tailpipe emissions (0-3000 ppm range) and other data are logged at 0,5 Hz interval. For every two (2) minutes of system operation, a data file will be automatically created and uploaded to the Cloud in order to ensure that the most recent data is available.

Extracts of data (date to date) can be made for the whole usage period. Further back pressure data, back pressure alarms, GPS position and AdBlue level status is stored and shown on the telemetry system.

- Presentation of **fleet emissions** Proof for municipality and authorities
- **Measurement in real time** through NOx sensors
- **NOx concentration** up- and downstream SCRT- System
- **NOx emissions reduction** (in% and g/km or g/100km
- **System diagnostics** (Error codes, remote diagnostics)

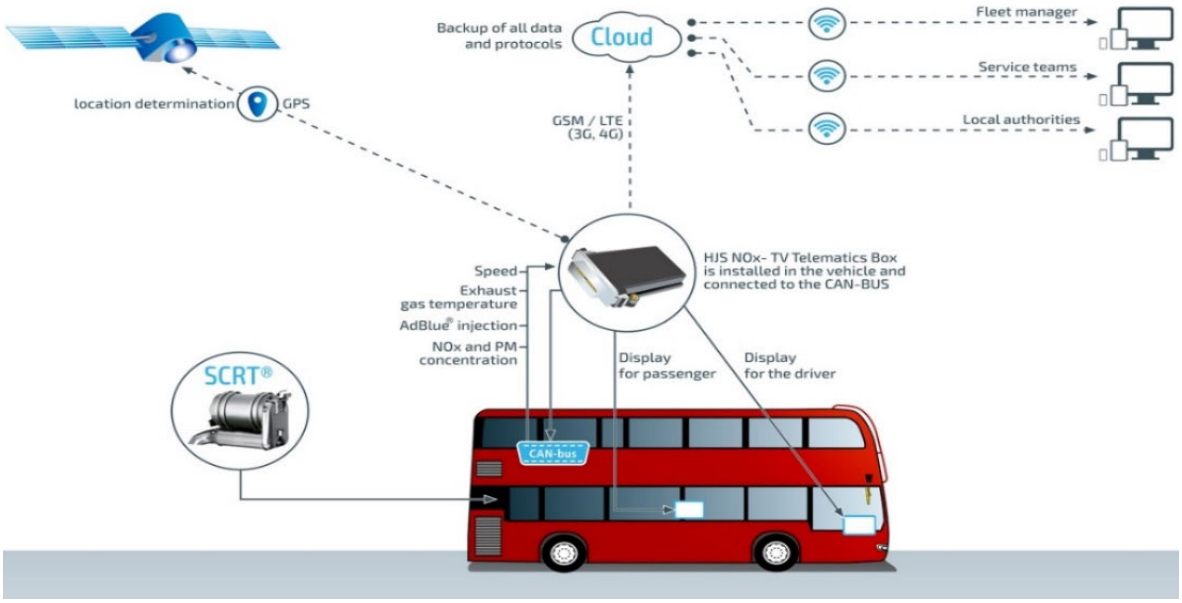


Figure 6: Remote Monitoring

Chapter 10

Technology Solutions

Reflecting the categories from the RFI paper

HJS Particulate Filter (SMF®) Technology

HJS particle filters hold back the soot particles effectively in their interior, including fine-grain dust, and clean themselves of deposited soot continuously and autonomously.

For the reduction of the soot gathered in the SMF®, the well-proven HJS-SMF® technology with passive regeneration is used. The HJS system combines a high-efficiency, upstream-connected diesel oxidation catalyst (DOC) with an SMF®. As a result of an optimum system coordination, the filter is freed up continuously and effectively from the deposited soot. The particle filter can be supplied with a catalytic coating for the support of regeneration.

Above an exhaust gas temperature of 200 C, the regeneration (cleaning) of the filter starts. The nitrogen dioxide formed with the aid of an oxidation catalyst (NO_2) impinges on the deposited soot on the filter bags. The soot particles are oxidized and reduced in this case; the NO_2 previously formed is reduced again to nitric oxide (NO).

As a result of this chemical process being repeated continuously, the HJS partial-flow sintered-metal filter cleans itself continuously and usually does not require any additional regeneration aids, such as for example a support of the engine management.

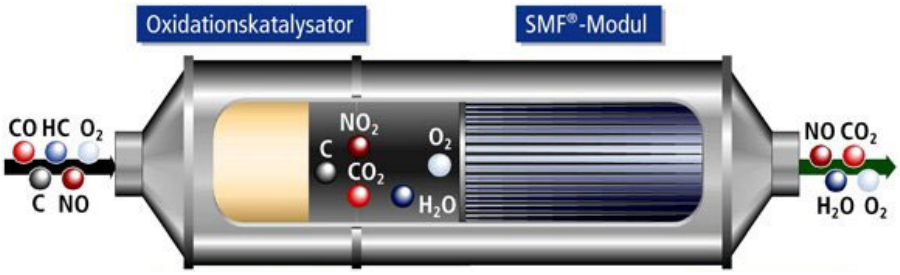


Figure 7:: Diesel Particle Filter Technology

Areas of application

The SMF® CRT® system is also mainly suited for off-highway applications, for commercial vehicles and buses, as well as, in combination with a SCR system, for nitrogen oxide reduction. This technology is used for construction machinery, stationary engines, rail and marine. HJS SCRT® systems are available both for application in the original equipment and for retrofit.

1. Diesel Particulate Filter (DPF) and Gasoline Particulate Filter (GPF)

Cars and Light-duty Trucks (LDT)
(RFI Ref.4.4.3-4)

In line with the introduction of the latest emission levels (Euro VI) all passenger cars are equipped with a particulate filter in Europe.

The HJS filter can be designed to a specific filtration rate. This SMF technology combines the advantages of a high filtration rate with a high level of safety and functional reliability. The technology can also be used under unfavorable boundary conditions without the need for complex regeneration management.

The filtering grade required for the respective application can be adapted in a wide range with this HJS technology. Practical experience indicates that the partial flow sintered-metal filter is almost maintenance-free since, as a result of its special design, significantly less ash component parts deposit than with other systems.

For the support of the regeneration, the HJS partial-flow sintered-metal filter can also be delivered with a catalytic coating. HJS has developed a rugged and efficient partial flow filter on the basis of the well-proven SMF® technology. The efficiency is optional from 30% – 80%. A full flow filter will reduce the emissions up to 95 %.

Figure 8:
Diesel Particle Filter for Cars and Light Duty Trucks

In the best case, the original oxidation catalyst (DOC) from the car manufacturer can continue to be used. This is supplemented by the Filter, which cleans itself while driving thanks to its catalytic coating.

The SMF does not require an additive to function, nor does it cause higher fuel consumption. During normal driving, the soot particles are chemically regenerated with the nitrogen dioxide in the exhaust gas the filter regenerates. Even ash from burnt engine oil does not pose a problem. The filter's high ash tolerance meets all the service life requirements of passenger cars. It can be installed in less than an hour working time.

Indicative unit prices

Serial system price: $800 - $1,800

Serial system price installation $700 - $900

HJS SCRT® Technology

- SCRT® is known as **S**elective **C**atalytic **R**eduction consisting of **d**iesel **o**xidation **c**atalysts (DOC), **d**iesel **p**articulate **f**ilter (DPF) and NO_x reduction devices. The system injects a liquid reductant agent through a special catalyst into the exhaust stream of the diesel engine.
- The reductant source is standard automotive-grade urea, otherwise recognized as **d**iesel **e**xhaust **f**luid (DEF). SCR is one of the most cost-effective and fuel-efficient technology available to help reduce diesel engine **NO_x** emissions.
- The DEF can be rapidly broken down to produce the oxidizing ammonia in the exhaust stream. It initiates a chemical reaction that converts nitrogen oxides into nitrogen, water and tiny amounts of carbon dioxide (CO_2), natural components of the air we breathe, which are then expelled through the vehicle tailpipe. The SCR technology alone can achieve NO_x **reductions up to 97 percent**.
- Many of the same advances can also be applied to **existing fleets** to reduce targeted pollutant emissions from older diesel engines. We call this measure “retrofit” or **“upgrade”** to newest exhaust gas emission standards.
-

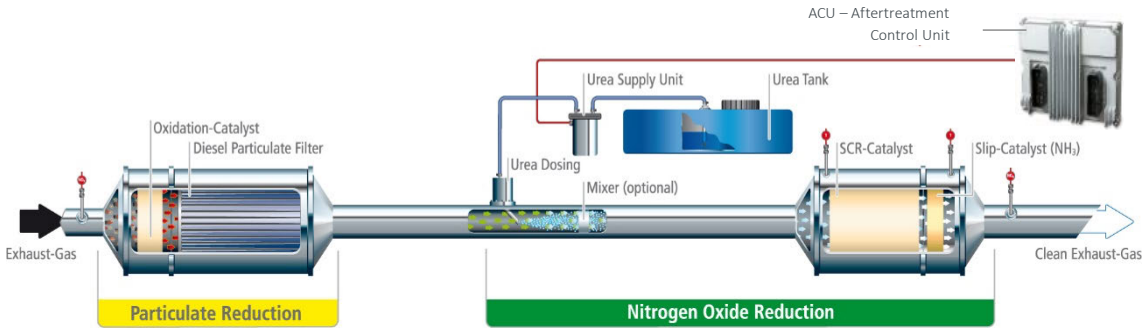


Figure 9: SCRT Technology Chart

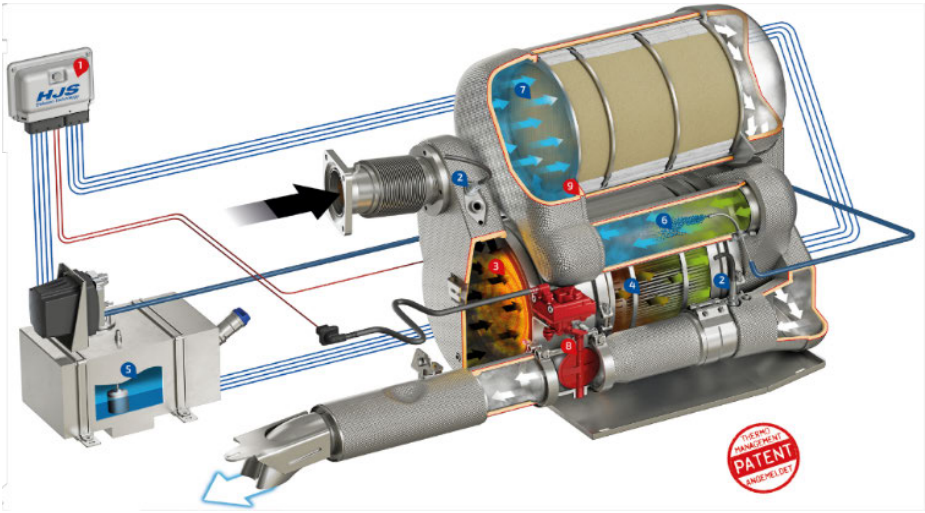
- Upgrades are highly effective, also eliminating up to **97** percent of pollutants in many cases. Upgraded vehicles operating in critical **low temperature cycles** often achieve significantly lower NO_x-emission values than comparable "standard" OEM solutions.
- Another advantage of upgrading: Emission requirements can be met with **existing infrastructure**, evident by fast improvement of the air quality values with little effort. Technology and products for upgrading of commercial diesel vehicles in operation are available and proven in various practical applications.

2. HJS SCRT® Systems

Trucks (HDT) and Buses
RFI Ref.4.4.1-2

Modern trucks and busses offer a maximum of exhaust gas cleaning through the combined employment of particle filter and SCR technology. However, buses in inner city transport frequently do not reach the temperature required for an optimum functioning of the SCR catalyst. The vehicle manufacturers meet the high requirements of emission standards primarily through the employment of engine Thermo-Management (TM). HJS transfers this concept, as an autonomous system architecture, to the retrofit of existing vehicles.

The HJS SCRT® system with active thermo-management also reduces health-endangering nitrogen oxide emissions of diesel engines by more than 90% even in demanding real-life operation.



1. Control Unit
2. NOx-Sensors
3. e DOC
4. DPF
5. DEF Tank
6. DEF Mixing Section
7. SCR Catalyst
8. Exhaust Flap
9. Integral Insulation

Figure 10: SCRT® with Active Thermal Management

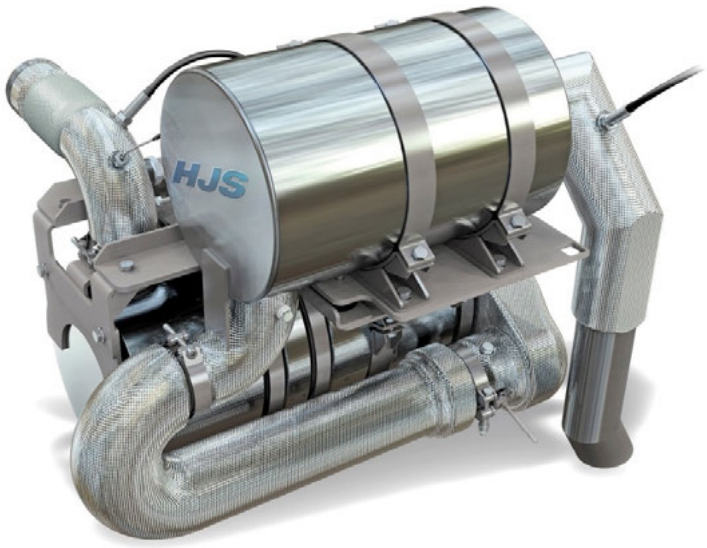


Figure 11: SCRT® for Alexander Dennis bus ADL E200

Indicative unit prices: Serial system: $15,500 - $20,000; Installation $2,000 - §5,000

SPEC SHEET

HJS SCRT® TM integrated exhaust system with active Thermal-Management

100% clean

Exhaust-gas Aftertreatment	SCRT® TM with active Thermal-Management
DPF® system	
Soot particle reduction rate	> 99 % (Particulate number)
Filter volume	19,5 l
Diesel oxidation catalyst (DOC)	integrated eDOC, eDOC volume: 7,2 l (6,4 l + 0,8 l)
Filter material	12" x 10,5" Corderiet coated
Regeneration	Continuously (CRT principle)
Service interval (filter)	> 125.000 miles / 5000 - 10.000 h
SCR system	
NO_x reduction	85 % - 94 %
SCR catalyst	Volume: 29,7 l including NH_3 blocking catalyst
AdBlue dosing system	Air – Assisted and Air – Less (on request)
Thermal-Management	
eCat	Heating power: 1,6 kW @ 28 V Temperature gain: 85 °F
eFlow accuator	Temperature gain: up to 70 °F
Complete system	
Housing material	Stainless steel, completely intergral insulated
Weight	approx. 93,0 kg
Operation voltage	independant HJS control module
Communication & Diagnose	CAN, HJS Diagnosis, HJS Remote Monitoring (optional)
Sensors	NO_x- , Temperature and pressure sensor

THERMAL MANAGEMENT PATENT PENDING

KRAFTFAHRT-BUNDESAMT ABE Allgemeine Betriebserlaubnis General Vehicle Type Approval

Application Example	Medium Duty / Heavy Duty / Mobile Machinery
Displacement	6 l - 12 l
Cylinder	6
Rated Power	up to 350 kW

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HJS Emission Technology

Figure 12: SCRT® Spec Sheet

3. NOx reduction solutions (SCR)

Light Duty Truck (LDT)
RFI Ref. 4.4.2

Light **D**uty **T**rucks (LDT) are able to move merchandise quickly, particularly in cities, and are beginning to make up a considerable proportion of fleets. For all companies, large and small that are building up a delivery service or have an existing one, LDT are an important tool. LDT are for example flatbed and pick-up trucks, vans and emergency ambulances for humans. The **U.S. Tier 3** standards phase in from 2017–2025 and apply to vehicles up to 14,000 lbs gross vehicle weight.

LDT are different from passenger cars and therefore require a different service level. Drivers have to make many stops, open and close doors. LDVs make an essential contribution of supplies into urban centers.

In the **United States**, 1.5% of all light-duty vehicles were diesel-powered in in 2014. About 4 % of the diesel fleet account for around half of the on-road NO_x emissions in the **US**.[15]. Once fully phased-in, Tier 3 tailpipe PM and NO_x emission limits for light- and medium commercial vehicles are the most stringent in the world.[16.]

To achieve highest NO_x conversion, the SCRT system, equipped with an **Active Thermal Management,** is designed and equipped for further optimization of functionality and performance with an electrical heating element named **eDOC**.

System Technology

The system has been designed with an integrated electrical thermal management device to increase the exhaust gas temperature and thus keep the system active even at low load operation.

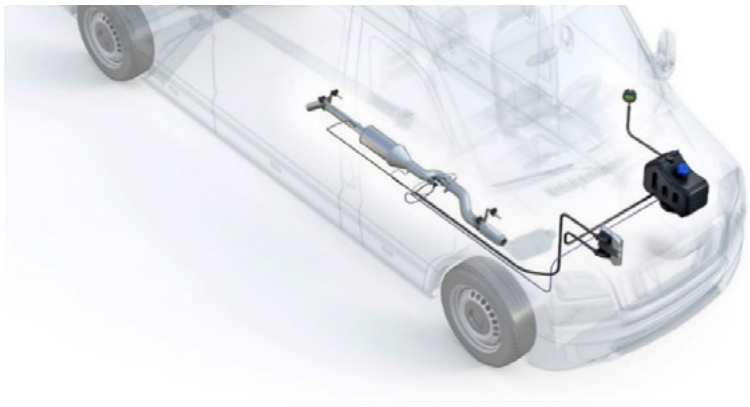


Figure 13: SCR for LDT

A highly efficient Diesel Exhaust Fluid (DEF) mixing section is combined with a copper zeolite SCR, which can be varied in length. A three-stage electrical heater has been integrated to realize a heating power respectively. A highly sophisticated control structure for the control and diagnosis of the electrical heater has been created and implemented into the HJS ACU control module. The system performance in **Real World Operation** is up to 89% reduction.

Indicative unit prices: Serial system $8,500; Installation $1,000

[15] https://www.bts.gov/archive/publications/bts_fact_sheets/oct_2015/entire
[16] https://www.dieselnet.com/standards/us/ld.php

4. NOx reduction solution - Three Way Catalyst (TWC)

Gas powered buses
RFI Ref. 4.4

Gas powered buses are an integral part of the public transit fleet with an existing infrastructure for operation, refueling, repair and spare parts procurements. On the basis of efforts to significantly reduce CO_2 emissions, this drive type is gaining more importance as the energy can be obtained from renewable sources. Upgrading of gas buses to the highest emission level on this basis is very essential contribution for health and air quality.

State of the art

Gas powered buses have positive ignition (PI) engines, where the exhaust aftertreatment are managed with a Three-Way Catalyst (TWC), similar to the catalyst used for gasoline cars.

Incompletely burned methane is oxidized to carbon dioxide and water with the help of catalysts. In the TWC hydrocarbons, CO and NOx generated during the combustion process can be efficiently converted to CO_2, H_2O and N_2. However, the engine must be operated, with a very tight control of the fuel-air-ratio where neither fuel or air is in excess, for the TWC to clean out the pollutants efficiently.

Advanced beyond the state of the art

HJS provides a specially coated TWC optimized for compressed natural gas (CNG) engines. The TWC is either installed in a new emission system replacing the original TWC system or is alternatively mounted as an add-on system in combination with the original TWC system, depending on the engine and exhaust design on the individual vehicle types.

The TWC are manufactured as modules that can be combined according to different engine power and displacement. The medium used is a metal or ceramic substrate with an effective wash coat and a rhodium, palladium, or platinum coating.

Figure 14: Adopted TWC

The HJS CNG Upgrade System reduces raw NOx emissions in the World Harmonized Vehicle Cycle (WHVC) in cold and warm starts by well over 90 % (measured weighted 96% and 97%).

This means that the HJS CNG Upgrade System is significantly more efficient in terms of reducing NOx emissions compared to the original exhaust system measured by approx. 62%.

Indicative unit prices: Serial System $9,000 and $12,500; Installation $1,500

5. Soot and NOx reduction solution SCRT

Construction Machinery / Rail / Generators / Marine
RFI Ref. 4.3

More alternative upgrade application

Figure 15: Gipo Stone Crusher - CH
Caterpillar C-13; 354kW @ 2200rpm Stage IIIa, Stage V Target, Airless-Dosing System

Figure 16: Piling Rig BG 40 – UK

Figure 16: AHLMANN Loader AZ95F – NL

Figure 17: Upgrading of Locomotives and Trains

Figure 18: Amtrak Tunnel Project, Long Island City, NY

Figure 19: Pickup Truck
Pickup Truck, Sudbury, Ontario

Figure 20: Utility Truck Scissors Lift, Detroit, MI

Figure 21:
Haul Truck, Marquette, MI

6. Soot reduction HJS DPF-System with Active Regeneration (SMF®- AR)

Off road equipment
RFI Ref. 4.3

For application-neutral employment of SMF®, the requirement for a corresponding regeneration process has been determined. For this, HJS uses an additive-supported, thermo-electrical, regeneration process, including ECU control unit, developed by HJS. This system, protected world-wide according to patent law, has for example a market share of approx. 70% in construction machines in Switzerland.

Figure 22:
SMF® AR System design

The SMF® AR system is ideally suited toward applications exhibiting low exhaust gas temperatures. The SMF® AR System (Sintered Metal Filter with Active Regeneration) regenerates autonomously regardless of the exhaust gas temperature. The system uses a fuel additive which lowers the soot ignition temperature and increases the soot burn off speed.

Actively regenerated particle filter for individual requirements

With this system, the particulate filter can be regenerated at almost every engine operating point regardless of temperature as the required temperature for soot burn off is generated by the SMF® AR system itself. Thanks to its compact design and construction and the modular structure of the system the SMF® AR system can be adapted to suit many different applications. The inlet and outlet pipes as well as the mounting brackets can also be tailored to suit a range of machines and vehicles.

Advantages

- Reduction of soot and ultra-fine particles by more than 99%
- Filter regeneration at low exhaust gas temperatures
- Regeneration without using a Diesel Oxidation Catalyst (DOC) enabling operation with high Sulphur content fuel
- Flexible adaptation to different machines and engine powers outputs
- High ash storage capability ensures long service life
- The modular assembly facilitates dismantling of the system for service
- The reduction of regeneration temperatures by 150°C.

Modularity

In order to enable the most economical integration into a range of applications, the SMF AR system is structured in a modular format. The size of the filter, the housing shape and the inlet and outlet cones can be selected based on the requirements of the installation space available.

Technology and functioning method

In the case of the SMF® AR system, exhaust gases are filtered until an optimum quantity of soot has collected on the filter. The system uses a fuel additive which lowers the soot ignition temperature and increases the soot burn off speed. The soot collected can therefore be burned off at an exhaust gas temperature of over 400°C. If the necessary temperature is not reached, as is frequently the case at low load range, the active regeneration support of the system is used in the form of thermo-electric heating elements.

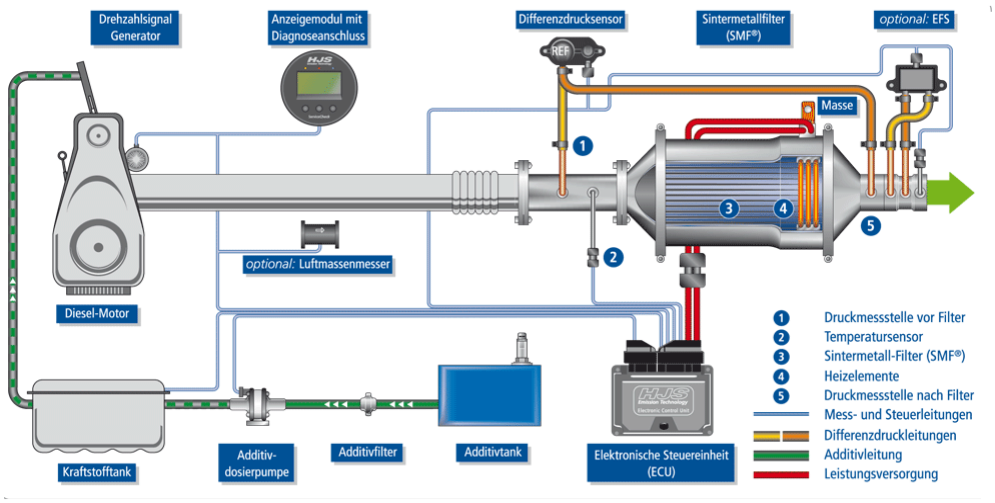


Figure 23:
SMF® AR System Regeneration Procedure

Active regeneration with additive

The system control unit initiates the active regeneration which comprises of heating elements which circle the filter. This process is implemented at regular intervals with the aid of a control unit. The control unit also uses sensors to detect the quantity of additive required, the soot load on the filter and also determines the best time to regenerate the filter.

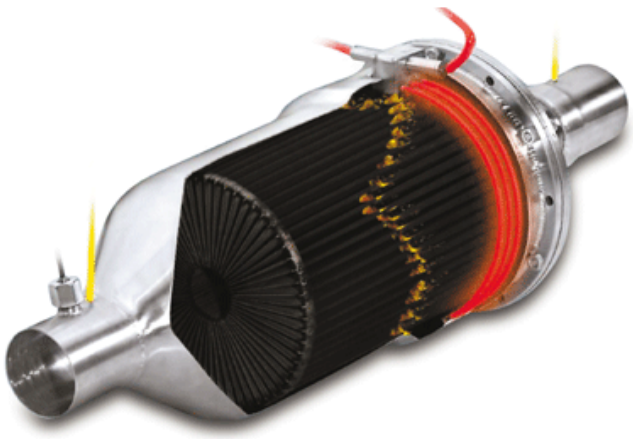


Figure 24:
SMF® AR System Regeneration Procedure

The SMF AR system also self learns the driving cycle to help prevent vehicle ignition switch off which interrupts the regeneration process. As a result of the high soot storage capability of the SMF® AR system, the regeneration is implemented where there is sufficient time rather than at a single time. Any interruption of regeneration by switching off the engine has no negative effect on the function of the system. Another important key aspect of the SMF® is that its high ash storage capability enables long maintenance and cleaning intervals.

Area of application

The SMF® AR system is predominantly suited for off highway applications but can also be applied to commercial vehicles and buses. It can also be used in combination with an SCR system for Nitrogen Dioxide reduction. This technology can also be used for static engines and railway or marine engines. HJS-SMF® AR system applications are available for both original equipment and for retrofitting.

- Suitable for OE-Applications and Retrofitting
- **> 99% Reduction of** soot particles incl. fine particles
- Suitable for urban traffic („Stop-and-go mode “)
- Automatic Active Regeneration
- Modular System
- Reliable System and low maintenance

Indicative unit prices:

From $3,000 for 80 kW up to $8,000 for 150 kW excl. installation

7. Soot and NOx reduction SCRT® System Barge (Stax)

Construction Equipment / Rail / Generators / Marine
RFI Ref. 4.3.3-4

Figure 25:
Barge System Technology

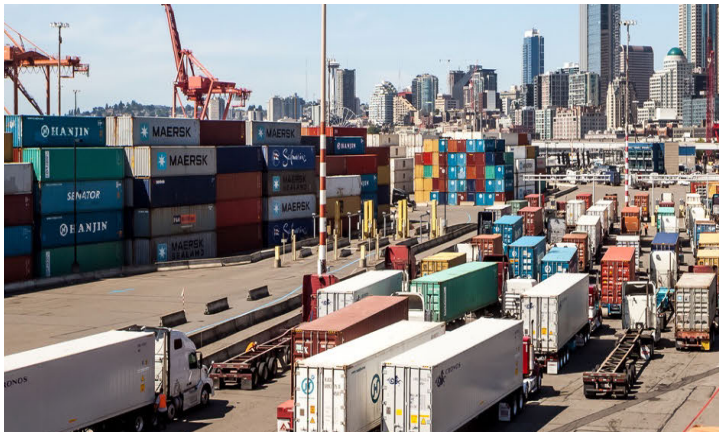


Figure 26:
Harbor Equipment

Large ocean-going vessels such as container ships and cruise vessels make use of shore power, while berthed, to run auxiliary engines, boilers, and other vessel operations. Shore power is capital intensive for shipping lines as the vessels need to be retrofitted with additional equipment. Emission control, while the vessel is in the berth, is critical since port cities get polluted with particulate matter, carbon dioxide, and other pollutants. Stax develops emission reduction solutions for vessels in ports to tackle global warming.

STAX system consists of a modular technology that is adaptable to every unique application. Each application consists of:

A mobile platform

The platform can be water based (barge, boat) according to the photo above or land based (truck pulled trailer, train based). The mobile platform can be designed to be driven over the roads or pulled by off-road equipment (locomotives, yard trucks, tugs) or can be self-propelled (powered barge). In cases where the source visits the same place or is not moved often, the platform can be semi-permanent and designed to be easily moved when needed.

A capture system

The STAX system comprises of the Xcap™ exhaust capture system which connects to the vessel's exhaust pipes, collects exhaust gas, and conveys the exhaust gas to the STAXbox™ purification system. The Xcap™ capture arm can reach exhaust pipes on the largest vessels. The Xcap™ exhaust capture hood is a significant improvement over the traditional approaches and is designed to collect ~100% of the exhaust gas from each exhaust pipe. Xcap™ also minimizes extra outside air. Processing clean outside air requires the system to be much larger than necessary, uses much more energy, and can "choke off" system capacity.

A purification system

The STAXbox™ "A" purification system is based on proven emissions control technologies. These proven technologies plus experienced system integration and patented features result in best-in-class overall effectiveness. The STAXbox™ "A" comprises of a Diesel Particulate Filter (DPF), a Selective Catalytic Reduction System (SCR) and a reactive organic gas (ROG) oxidation catalyst.

The STAXbox™ "B" includes carbon capture technology that can be added to the purification train. The purification system has a compact design built in modules based on the shipping containers for ease of transportation and minimizing the size foot print, making it a very flexible and easily implemented control system.

STAX has developed patent-pending technology to eliminate plugging issues through careful system integration and special active regeneration. The STAX DPF system also produces less pressure drop which saves operating (blower) costs.

The HJS DPF filter elements are VERT-certified to level "B" or >= 97% filtration rate for solid particle number.

The gas exiting the DPF is then pre-heated from energy recovered from the exhaust gas leaving the SCR system using a heat exchanger. The gas is then further heated and precisely controlled by a patented process to optimize the SCR operating temperatures. The SCR includes a high-efficiency catalyst and a non-hazardous urea reductant.

After passing through SCR catalyst, the exhaust gas passes through an ROG reduction system. The gas then passes through the heat exchanger to preheat the incoming gas to the SCR system, resulting in exceptional thermal efficiency and low operating cost. A specially designed blower draws the exhaust through the system.

The entire system is under vacuum, thereby precluding fugitive emissions. The fan speed is automatically controlled, resulting in near-zero back pressure on the serviced vessel's exhaust system. A fail-safe mechanical over-pressure system is used to guarantee that the engine sees little or no backpressure, even in the event of a power failure.

If desired a STAXbox™ "B" module can be added to the train to reduce carbon emissions. The CO_2 control technology is based on proven CO_2 capture technology where the gas is cooled to condense out the CO_2 for efficient storage and easy transport to sequestration facilities.

STAX Engineering's patented system based on time tested technologies is available for use today and can provide a bridge to zero emissions with little or no modifications for existing diesel engines. And in some cases, the technology can provide net negative emissions of GHG emissions if carbon capture is used with efuels.

The SMF Block Filter Technology

SMF Block Filter collecting up to 99 % of soot emission and are designed for rough operation conditions. They are extremely robust and can collect up to three times more soot and ashes than honeycomb filter. They can be cleaned in situ with water- or air pressure cleaner devices.

Figure 27:
SMF® AR System Regeneration Procedure

Emission Reduction-as-a Service

Stax Engineering offers Emissions Reduction-as-a-Service for ocean-going vessels at berth. The startup uses *STAXboxes*, a patented universal emissions control box to remove toxic emissions and capture carbon at the source. The *STAXboxes* easily attach to already existing emissions sources such as auxiliary anchor boiler, diesel generators, and main boiler. *STAXboxes* capture particulate matter, nitrogen oxides, and sulfur oxides, as well as carbon dioxide and short-lived climate pollutants (SLCP).

Chapter 11

Best Practice Examples

Real Word Expertise

Large upgrading campaigns for buses were carried out by HJS in numerous metropolitan areas in the **UK, Italy, Spain, and Germany**. Similarly, large retrofitting measures with significant HJS involvement took place in **Chile, Mexico, and China**. All projects are best practice examples of measures how and where significant improvements in air quality were achieved by upgrading. We will be happy to provide further information in this respect.

On 21 October 2019, the Mayor of London announced that in the two and a half years since the introduction of the Toxicity Charge and the Ultra-Low Emission Zone (ULEZ) in the UK capital, nitrogen dioxide (NO2) pollution in the zone has reduced by 36%. The ULEZ itself is estimated to have contributed 29% of the improvement.

Ambitous Targets for Air Quality in the UK

'An issue of life and death': Sadiq Khan, the Mayor of London's bold air quality plans.

"With nearly 10,000 people dying early every year in London due to exposure to air pollution, cleaning up London's toxic air is now an issue of life and death," said Khan. "It is the 60th anniversary of the Clean Air Act of 1956, which was passed following the great London smogs of the 1950's. Today we face another pollution public health emergency in London and now it's our turn to act."

© Photograph: Graeme Robertson for the Guardian

To help improve air quality the Mayor of London will be introducing a Ultra Low Emission Zone (ULEZ) this will be implemented in Central London from 8 April 2019.
Most vehicles including cars and vans will need to meet new, tighter exhaust emission standards or pay a daily charge to travel withhin the area.
The Mayor has also set out his ambitious plans to extend the Ultra Low Emission Zone by 2021 to include the whole of Greater London. The ULEZ will help reduce exhaust NOx and PM emissions, helping to improve air quality and making Central London a safer and more peasant place to live, work and visit.

HJS has upgraded up to 20.000 city buses in the major cities of Europe, especially Madrid, Berlin, London, Birmingham, Manchester within 2010 - 2021

NOx Reduction > 95 % within MLTB (CVRAS)

ARRIVA national express abellio Stagecoach UK BUS LONDON UNITED RATP GROUP First

HJS Retrofit References

Country/Region	1.000	Type of Usage
Switzerland	50	Construction Machines
USA California	400	Truck and Bus
Korea	400	Truck
Japan	180	Truck and Bus
European Union (except D, DK, BE, Lux)	200	Truck and Bus
Belgium, Denmark, Germany, BE, Lux	2.500	Passenger Car
Israel	15	Bus
Mexico, Chile, Brazil	10	Bus
China	220	Passenger Car

Figure 18:
HJS Retrofit References of installed after treatment systems

	2001 - 2005			2006-2010			2011-2015			2016-2020			
	Bus	Truck	NR*	Bus	Truck	NR	Bus	Truck	NR	Bus	Truck	NR	Total
Switzerland	3	1	7	2	1	11	3	2	16	-	1	8	55
Germany	20	-	-	25	50	-	5	50	0	-	-	40	190
Italy	10	-	-	20	-	-	15	-	-	-	-	-	45
France	7	-	-	3	-	-	2	-	-	-	-	10	22
Great Britain	9	11	-	-	12	-	-	10	1	-	-	5	48
Rest of the EU	15	-	-	15	-	-	15	-	-	-	-	-	45
Within the EU	-	-	50	-	-	75	-	-	75	-	-	50	250
USA	20	10	-	12	22	2	20	28	7	10	20	10	161
Latin America	-	-	-	3	-	-	1	-	-	10	40	10	64
Iran	-	-	-	-	-	-	-	-	-	8	35	2	45
Israel	-	-	-	-	-	-	-	-	-	4	5	2	11
Korea	10	20	-	20	130	-	20	80	-	20	70	-	370
Japan	30	30	-	30	30	-	30	30	-	-	-	-	180
China	-	-	-	4	4	-	15	10	1	50	30	50	164
Rest of Asia	15	-	-	15	-	-	15	-	-	25	-		70
Sum	139	72	57	149	249	88	141	210	100	127	201	187	
Total		268			486			451			515		
Total					1,205 (Europe: 541)						7		1,720

Figure 27:
Retrofit References of installed DPFs with VERT[17] Certification in 1,000

[17] Association dedicated to the promotion of Best Available Technology for emission control - Switzerland

Chapter 12

Installation, Repair and Maintenance Services

IRMS

Installation

Installation of DPF systems require care and attention and the quality of the work is essential to providing long-term performance. TF Hudgins provides the complete installation of DPF System components through local installers trained and under the direction of TFH engineers. The installation can be performed at the customer maintenance shop or off site as required.

The work environment is an essential element of installation and TFH can provide union labor where required. Our focus is on safety, quality, and schedule.

We operate and conduct operations with high safety standards for all aspects of our work. We use proven procedures and training to ensure installations are of exceptional quality and performance. We provide on-time outcomes for each installation. Each system installed is commissioned and operated, we establish baseline data for performance over the life of our filters. Installation supervision ensures safe and trouble-free operation and maximum usability.

Installation of DPF Systems and Components include:

- Review of contract documents and overall works
- Solve organizational issues of installation
- Provide technical preparation of the project
- Project implementation:
- Supervise / train installers and technicians
- Supply all equipment and additional spare parts as required
- Delivery of a fully working installation
- Carry out commissioning, output equipment to the declared capacity
- Complete the installation by drawing up an act of the work done and acceptance of the installation by the customer.

Repair & Maintenance

- TFH can provide training for Port Authorities maintenance organizations covering all aspects of routine maintenance and for troubleshooting. Trained representatives conduct routine system audits and verify performance of the filters.
- TFH can also perform repair and maintenance of installed systems under contract using our supervision in conjunction with the local workforce.
- TFH will maintain a local inventory of spare parts.
- TFH provides Service and Troubleshooting Manuals and maintains a 24-hour help line.
- All repair history and system alarms are logged and stored in the cloud for analytics and historical purposes.
- The SCR systems have on-board software, diagnostics, and historic data storage that enables technicians and users to track and record the operational history of each installed system. The information can be downloaded on to a portable storage device and then

analyzed and reported. Each system will have its history stored for reference and assessment.

Partnering

TF Hudgins, through our Allied Reliability division provides staffing services to a variety of large companies, Anheuser-Busch, Kraft Foods, Mosaic, Exxon, Chevron, and many others. We provide maintenance, scheduling, and repair training as a consulting business. We actively seek and work with accredited partners to fulfill many contracts we work on.

Maintenance Monitoring

TFH is able to monitor the performance of the DPF systems for the period covered and agreed on in a separate contract.

The following performance metrics are noted as follows:

1. PM capture rate: 90% or better
2. NO_X: 25ppm or less
3. CO: 400 ppm or less

The installations entail HJS Filter Systems that will be installed and commissioned by TFH. Emission data prior to the DPF installation is required by TFH and will be tested and recorded by TFH.

The data shall include:

- Exhaust temperature
- PM count
- NO^X values
- CO values (raw, from engine output with no aftertreatment)
- Hydrocarbons

Emission tests are to be performed in accordance with accepted industry standards.

TFH will perform and provide emission testing and data on a weekly basis

Repairs and filter modifications will be conducted by TFH or its designate under our supervision and guidance.

Chapter 13
Certification
International approvals

- Both the US and EU have a major goal which is to reduce the instances of air pollution from the transport sector. Emission standards in European countries has been more productive owing to the impacts on the reduction of greenhouse gases.
- The City of New York passed emission legislation in 2003 (Section 24-163) requiring city vehicles to use the best available technology for reducing the emission of pollutants along with requirements for the use of low sulphur fuel.
- Retrofitting of engines in use is fundamentally different from certifying new engines. A variety of different certification procedures exist for retrofitting diesel engines with diesel particulate filters (as illustrated below). What they all have in common is that certification takes place on the engine test bench or chassis dynamometer. Current exhaust gas regulations in Europe are now also measured with Portable Emission Measurement System (PEMS) in real operation.
- Emission laws in European countries are more robust and all-encompassing than in the US and other parts of the world. The EU directive on the reduction of noxious emissions from vehicles, which was introduced in 1992, has been revised continuously to accommodate recent developments in the transport sector. The stringent nature of these directives has led to a significant drop in vehicle emissions over the years.
- The 6th incarnation of the EU emission standards, otherwise known as Euro VI aims at reducing pollutants such as NOx, Carbon Monoxide (CO), Hydrocarbons (HCs) and Particulate Matter (PM) with a focus on combatting climate change. The most significant aspect, like its predecessors, is the different measures for diesel and gasoline vehicles. Also, supporting the emission reduction efforts of the EU is the rising popularity of diesel vehicles which has contributed to the reduction of CO_2 emissions.

Portable Emission Measurement Systems (PEMS)

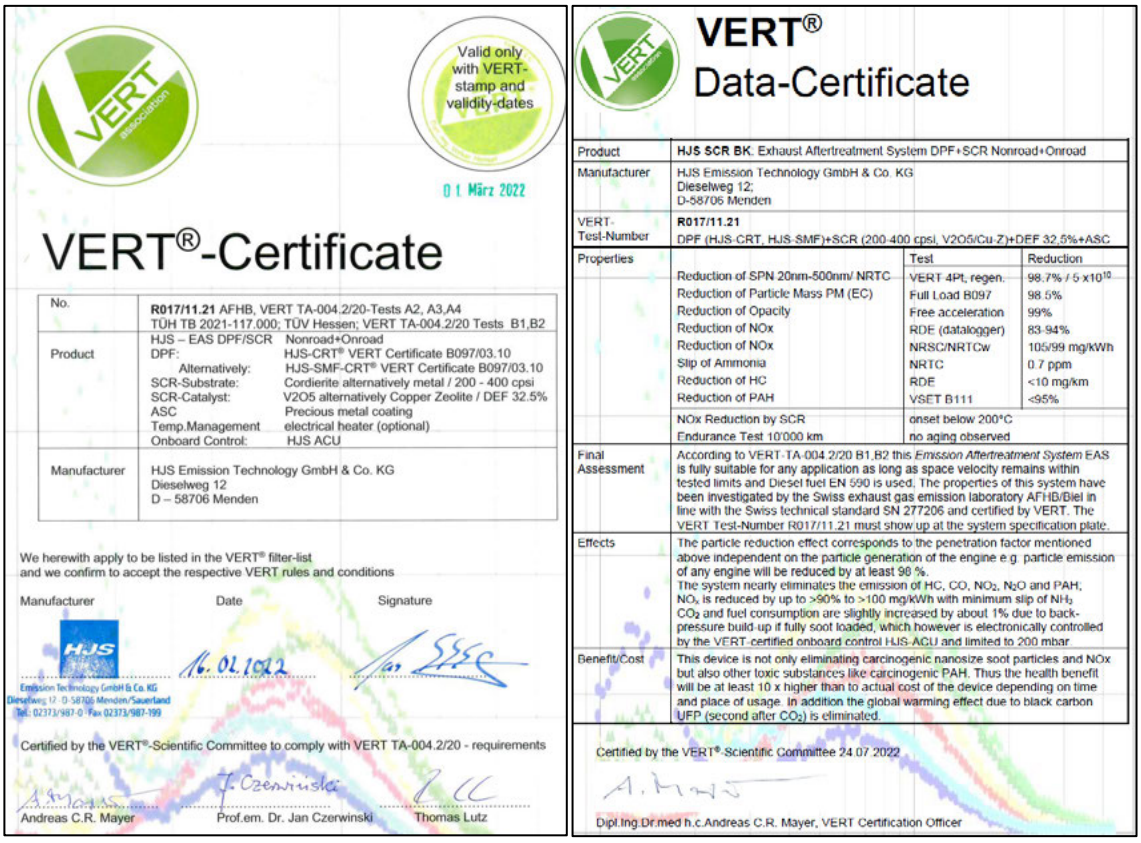
- In Europe, certification procedures have already been established that are based on PEMS measurements and consider the typical load profile of the respective application.
- This is a physical-chemical process that is independent of engine manufacturer or engine approval, but depends only on exhaust gas mass, temperature, and composition. Since these three factors change with the mileage of the engine and the load profile resulting from the respective application of the machines or the engine, it makes sense to determine the quality of a retrofit emission reduction device via the efficiency. The efficiency is calculated from the difference of 1 and the quotient of tailpipe emissions to engine out emissions and is usually given as a percentage.
- While the efficiency of full flow diesel particulate filters is above 98% under almost all operating conditions, the reduction achievable with nitrogen oxide reduction systems also depends on the exhaust gas temperature. Low-temperature operation can cause the reagent injected into exhaust gas Diesel Exhaust Fluid (DEF) to fail to evaporate and form deposits that can clog the emission control system.
- If required, HJS SCR systems are equipped with exhaust gas heaters that significantly extend the temperature range in which nitrogen oxide emissions can be effectively reduced. The effectiveness of the so-called thermal management can only be evaluated in real operation with the help of PEMS measurements.

VERT Certification[17]

Worldwide efforts to curtail particle emissions from combustion engines have produced a plethora of technologies. VERT® has been the pioneer in this field since 1993. The AKPF (Working Group for Particle Filters) subsequently collaborated with the regulatory authorities and industrial partners to formulate a set of criteria. These include highest requirements in filtering the alveoli-intruding solid particles, preventing secondary emissions, guaranteeing dependability and cost effectiveness of the systems and assuring the best retrofit practice. VERT® only approves systems which comply with the best available technology (BAT) definition and are proven in field deployment; which holds for both new and retrofitted older deployed Diesel engines.

High filter quality also results in cost effectiveness because it diminishes treatment costs for many serious ailments. These include cancer, cardiovascular diseases, allergies, asthma and probably even Parkinson's, Alzheimer's and other widespread diseases. VERT® is highly committed to implement the latest medical and scientific findings. The filter approval criteria will be periodically adapted to reflect technological advances. Hence, this filter list will be updated twice a year.

The VERT® Association aims to provide methods of very efficiently combating both emission toxicity and black carbon induced global warming. Particle filters facilitate a sustainable environment. Newest certification procedures for On- and Non-Road applications include PM and NOx reduction.



VERT®-Certificate

Valid only with VERT-stamp and validity-dates

01 März 2022

No.	**R017/11.21** AFHB, VERT TA-004.2/20-Tests A2, A3,A4 TÜH TB 2021-117.000; TÜV Hessen; VERT TA-004.2/20 Tests B1,B2
Product	HJS – EAS DPF/SCR Nonroad+Onroad DPF: HJS-CRT® VERT Certificate B097/03.10 Alternatively: HJS-SMF-CRT® VERT Certificate B097/03.10 SCR-Substrate: Cordierite alternatively metal / 200 - 400 cpsi SCR-Catalyst: V2O5 alternatively Copper Zeolite / DEF 32.5% ASC Precious metal coating Temp.Management electrical heater (optional) Onboard Control: HJS ACU
Manufacturer	HJS Emission Technology GmbH & Co. KG Dieselweg 12 D – 58706 Menden

We herewith apply to be listed in the VERT® filter-list
and we confirm to accept the respective VERT rules and conditions

Manufacturer Date Signature

HJS Emission Technology GmbH & Co. KG Dieselweg 12 · D-58706 Menden/Sauerland Tel.: 02373/987-0 · Fax 02373/987-199

16.01.2022

Certified by the VERT®-Scientific Committee to comply with VERT TA-004.2/20 - requirements

Andreas C.R. Mayer Prof.em. Dr. Jan Czerwinski Thomas Lutz

VERT® Data-Certificate

Product	**HJS SCR BK**: Exhaust Aftertreatment System DPF+SCR Nonroad+Onroad		
Manufacturer	HJS Emission Technology GmbH & Co. KG Dieselweg 12; D-58706 Menden		
VERT-Test-Number	**R017/11.21** DPF (HJS-CRT, HJS-SMF)+SCR (200-400 cpsi, V2O5/Cu-Z)+DEF 32.5%+ASC		
Properties		Test	Reduction
	Reduction of SPN 20nm-500nm/ NRTC	VERT 4Pt, regen.	98.7% / 5 x10^{10}
	Reduction of Particle Mass PM (EC)	Full Load B097	98.5%
	Reduction of Opacity	Free acceleration	99%
	Reduction of NOx	RDE (datalogger)	83-94%
	Reduction of NOx	NRSC/NRTCw	105/99 mg/kWh
	Slip of Ammonia	NRTC	0.7 ppm
	Reduction of HC	RDE	<10 mg/km
	Reduction of PAH	VSET B111	<95%
	NOx Reduction by SCR	onset below 200°C	
	Endurance Test 10'000 km	no aging observed	
Final Assessment	According to VERT-TA-004.2/20 B1,B2 this *Emission Aftertreatment System* EAS is fully suitable for any application as long as space velocity remains within tested limits and Diesel fuel EN 590 is used. The properties of this system have been investigated by the Swiss exhaust gas emission laboratory AFHB/Biel in line with the Swiss technical standard SN 277206 and certified by VERT. The VERT Test-Number R017/11.21 must show up at the system specification plate.		
Effects	The particle reduction effect corresponds to the penetration factor mentioned above independent on the particle generation of the engine e.g. particle emission of any engine will be reduced by at least 98 %. The system nearly eliminates the emission of HC, CO, NO_2, N_2O and PAH; NO_x is reduced by up to >90% to >100 mg/kWh with minimum slip of NH_3 CO_2 and fuel consumption are slightly increased by about 1% due to back-pressure build-up if fully soot loaded, which however is electronically controlled by the VERT-certified onboard control HJS-ACU and limited to 200 mbar.		
Benefit/Cost	This device is not only eliminating carcinogenic nanosize soot particles and NOx but also other toxic substances like carcinogenic PAH. Thus the health benefit will be at least 10 x higher than to actual cost of the device depending on time and place of usage. In addition the global warming effect due to black carbon UFP (second after CO_2) is eliminated.		

Certified by the VERT®-Scientific Committee 24.07.2022

Dipl.Ing.Dr.med h.c.Andreas C.R. Mayer, VERT Certification Officer

Figure 28:
VERT[18] Certification procedure for PM and NOx reduction

[18] Swiss Association dedicated to the promotion of Best Available Technology

HJS International Retrofit Certifications

- Switzerland: SN 277206 (VERT)
- Germany: Annex 26 / 27
- Italy: Decret No. 39
- The Netherlands: RDW / TNO
- Malta: Informal application
- Denmark: Teknologisk Institut (202-5061-42)
- United Kingdom: LEZ (CV) LEC (CVRAS)
- Sweden: VVFS 2003:29
- France: Regulation of 15.05.2013
- United States: Mine Safety Health Administration (MSHA) 99% efficiency approved.

Port Authority VERT Approval

The Port Authority of New York and New Jersey allow VERT approved emission systems as cited:

- "Any properly installed and functioning system utilizing a Diesel Particulate Filter ("DPF") that primarily reduces emissions of particulate matter ("PM"), demonstrating an 85% or greater reduction in PM, and secondarily nitrogen oxide ("NOx") that appears on either the United States Environmental Protection Agency ("EPA") or the California Air Resources Board ("CARB") verified lists at *http://www.epa.gov/otaq/retrofit/verif-list.htm and http://www.ai~b.ca.gov/diesel/verdev/background.htm* for On-Road or Non-Road engines [or any properly installed DPF from either of tire verified lists].

- Category I (b) Any properly installed DPF from either tire EPA or CARB verified lists.

- Category 1(c) A filter that has undergone the Vermindening der Emissionen Realer Dieselmotoren im Tunnelbau ("VERT") test procedure and appears as approved for continuous use on the VERT list maintained by http://akpf.org/pub/vert filterliste.pdf or similar test procedures to those conducted by EPA/CARB and has demonstrated an 85% or greater reduction in emissions of PM.

- Category II Any properly installed and functioning system utilizing a [Diesel Oxidation Catalyst ("DOC") or Catalyzed Wire Mesh Filter ("CWMF")] Flow through Filter ("FTF") that primarily reduces emissions of particulate matter ("PM") and secondarily nitrogen oxide ("NOx") that…"

Clean Vehicle Retrofit Accreditation Scheme (CVRAS) UK

The Energy Saving Trust is a UK organization responsible for certification schemas.The Clean Vehicle Retrofit Accreditation Scheme (CVRAS) supports the operation of Clean Air Zones (CAZ) and addresses the air pollution emissions from buses, coaches, heavy goods vehicles, mini-buses, taxis and vans[19] The Certification scheme includes measures for PM and NOx emissions according to as typical city drive line cycle (Millbrook)

Certification procedures include also non-Road equipment like excavators, bulldozers, generators, forklifts, mobile cranes, etc.

It certifies the emissions reduction systems that can be retrofitted to NRMM (or construction machinery) to allow them to be used in areas which have emissions restrictions. **The Energy Saving Trust Association accepts the VERT approvals**

EPA - Emission Standards in the US

In the United States, due to the high level of air pollution and smog formation which has resulted in poor visibility, emission standards are focused on the reduction of oxides of Nitrogen (NOx) and particulate matter (PM). A reflection of this are the "Smog Laws" that were enacted across the US, employing varying processes and standards.

In addition, the high point of emission regulation in the US is the categorization of standards of vehicle types by the US Environmental Protection Agency (EPA). There are different regulations for Light-duty vehicles, Heavy Duty vehicles and non-road vehicles such as aircrafts and marine vessels. The Fuel Sulphur Standards are also in place to check diesel and gasoline for acceptable sulphur contents. However, these laws have not resulted in reduction of CO2 which is an important greenhouse gas of which the US emits double that of Europe. The domination of gasoline engines, due to cheaper gasoline in the US, has likely been a key factor in this.

[19] https://energysavingtrust.org.uk/service/clean-vehicle-retrofit-accreditation-scheme/

The 1998 nonroad engine regulations were structured as a 3-tiered progression. Each tier involved a phase-in (by horsepower rating) over several years. Tier 1 standards were phased-in from 1996 to 2000. The more stringent Tier 2 standards took effect from 2001 to 2006, and yet more stringent Tier 3 standards phased-in from 2006 to 2008 (Tier 3 standards applied only for engines from 37-560 kW).

VERT provides most the common and most stringent certification method in the world. It provides the highest performance and lowest emissions in line with endurance test runs. This results in a very high-quality technology and best in class.

HJS filters are VERT approved

Chapter 14

Implementation of Environmental Zones

Complementary measure

Clean air for the inhabitants in the urban area is the main goal of environmental zones, which have been so far introduced in main cities around the world.

- Low Emission Zones are geographical areas where the most polluting vehicles are regulated. Usually this means that vehicles with higher emissions cannot enter the area. In some Low Emission Zones (LEZ) the more polluting vehicles have to pay a higher fee/toll if they enter the LEZ. LEZ requirements are not harmonized across the EU rather, the particular LEZs are governed by different, local and/or country level regulations.
- Many regulations have been implemented according to labelling categories with limited access and operation restrictions within the Environmental Zones. These regulations can be adapted for on-road vehicles and off-road transport equipment. The awarding of labels and the regulation of machines, vehicles and equipment must be bindingly regulated in detail. The environmental zones must be clearly marked and identified.
- The Low Emission Zones (LEZ) were set up to encourage the most polluting heavy diesel vehicles driving to become cleaner. It covers most of the Cities and operates 24 hours a day, every day of the year.
- The retrofitting of older vehicles to the limits of the current regulation level will absolutely help to meet the necessary access requirements. Comparably similar arrangements now exist in Denmark, the Netherlands, Italy, and Sweden, among other countries.
- The City of Berlin and Greater London dictate that most vehicles which enter the Ultra-Low Emission Zones (ULEZ) in the City of London must pay under certain conditions a £12.50 daily charge if they do not meet the emission standards.[20]
- Emissions of nitrogen oxides (NO_x) are said to be 31% lower than they would have been without the ULEZ. In addition, carbon dioxide (CO_2) emissions in the central zone are 4% lower in the first six months of ULEZ operation. There are also on average 13 500 fewer non-compliant vehicles per day entering the zone than in March 2019.[21]. Thanks to the environmental badges, the emissions of particulate matter and nitrogen oxide (NOx) have been reduced drastically.[22]

[20] Comparably similar arrangements now exist in Denmark, the Netherlands, Italy, and Sweden, among other countries.
[21] www.gov.uk/government/news/government-introduces-ground-breaking-environment-bill and www.gov.uk/government/news/uk-to-go-further-and-faster-to-tackle-climate-change.
[22] Malina, C., Scheffler, F. (2015). The impact of low emission zones on particulate matter concentration and public health. Transportation Research Part A: Policy and Practice, 77, 372-385. https://www.wiwi.uni-muenster.de/fakultaet/de/news/447

Chapter 15

Partnering USA

Cooperation and reliability

Close US Co-operation with German Vehicle Manufacturers in the USA

Every second German car from US production goes into export
Production in the USA higher than imports from Germany

- "The USA is not only an important market for Germany's manufacturers, but more than ever also an important production location. Between 2009 and 2016, German manufacturers quadrupled their US production from 214,000 to 845,000 units, while US light vehicle production doubled (from 5,6 million to 11.9 million). German suppliers have tripled the number of their locations in the USA to 265–a clear commitment to the USA as a location." [23]
- It is the sustained interest of HJS and the Alliance of Clean Transportation to continue this tradition in the automotive supply sector by means of providing modern diesel exhaust systems to the American marketplace.
- In close co-operation with our American partners, HJS will further develop the market successfully. Reduction and elimination of polluted air in metropolitan areas and specific places like ports is our common goal accompanied by a significant share of the value added generated in the USA.

- The cooperation between environmental authorities, political institutions, operators, industrial companies, and suppliers is an essential element of our business. This includes strict sharing of forward-thinking ideas whilst providing state-of-the-art solutions that can improve the quality of air substantially.

- We are committed to our social responsibility worldwide. Integrity, sustainability, and legal compliance are the pillars of our business activities. We live the appreciation for people & the environment out of conviction and start in our own company. The responsible use of natural resources and the avoidance of negative environmental impacts play a central role in our day-to-day operations.[24]

- The Alliance for Clean Transportation between T.F. Hudgins and Stax Engineering with its German partner HJS Emission Technology supports and lives on these principles in the best sense of a mutually stimulating as well as fruitful American-German partnership.

[23] Matthias Wissmann, President of the German Association of the Automotive Industry (VDA), on the commitment of the German automotive industry in the USA, Berlin, May 25, 2017 [Excerpt]
[24] Excerpt from the HJS Corporate Policy Statement 2021

Chapter 16

Conclusion

Retrofit towards Zero Emission pays off

- Air pollution is one of the greatest environmental threats to human health, along with climate change. Improving air quality can also benefit climate change mitigation. Reducing emissions, in turn, will improve air quality.
- Transportion is an important economic sector, both for society and for individuals however, it´s a major source of air pollution, especially nitrogen oxides (NO_2) hydrocarbons (HC), carbon monoxides (CO) and particulate matter (PM) from combustion engines, which are harmful to human health and the environment.
- There are several upgrade options for in-use vehicles and equipment that meet even the most stringent international emission standards. Retrofitting of commercial vehicles in use as well as mobile non-road equipment is the most effective and economical solutions for moving towards zero emission.
- This upgrade technology is tested and approved, available and fast to install, without waiting for the fleet to be renewed which could last for years.
- **The estimated economic benefits of improved air quality far exceed the costs of implementing the measures[25].** Currently updated WHO Air Quality Guidelines of 2021 emphasize the importance of reducing air pollution concentrations at all levels.[26]
- The Alliance for Clean Transportation, T.F. Hudgins, STAX Engineering and HJS Technology, is characterized by excellent technical know-how, high quality standards, reliability, and local service readiness, along with a significant value-added share in the USA.
- Zero Emission strategies need both, speed and freedom to manage this change. Clean air in our cities, environmental and climate protection are issues that are mutually dependent. They are more topical than ever and our contribution is urgently required!

Retrofit towards Zero Emission pays off

We are looking forward to discussing this subject further with you soon.

Michael Mazzuca
Speaker of the Alliance for Clean Transportation
T.F. Hudgins, Houston TX ● Stax Corporation, Santa Barbara CA ● HJS Emission Technology, Menden, Germany
mmazzuca@tfhudgins.com

[25] For the U.S., it has been estimated that the benefits from reduced mortality, lower medical expenditures for air pollution-related illnesses, and increased worker productivity are about 30 times greater than the costs of the Clean Air Act, resulting in a net improvement in economic growth and population well-being (U.S. E.P.A. 2015). Similarly, in the EU, additional air pollution control and climate change mitigation measures that lead to net benefits with positive macroeconomic impacts over and above current obligations are ranked (Amann et al. 2017).

[26] https://www.ersnet.org - WHO/AQGs – WHO/Air Quality Guidelines 2021

Addendum 1
Contributors

Alliance for Clean Transportation

The technical and organizational cooperation of the two U.S. partners **T.F. Hudgins** and **STAX Engineering** with the innovative German emission control developer and manufacturer **HJS Emission Technology** for products and service solutions in environmental technology is characterized by convincing know-how, highest quality standards, reliable delivery capability and permanent on-site service readiness.

The Alliance for Clean Transportation supplies complete environmental technology products and services for exhaust gas cleaning of internal combustion engines that comply with strict international standards, right through to tailor-made and individual customer requirements. Fast, efficient, and reliable.

With their technically and organizationally coordinated supply, infrastructure, installation and service activities, the partners develop sustainable **local value-added shares** in the USA. Their cooperation, some of which have been in place for many years, extend beyond activities in the US territory with exports.

Company Profiles

T.F. Hudgins Incorporated, Houston, TX

T.F. Hudgins, Inc., Houston, TX, is the source for engineered product and service solutions for machinery used in a wide range of heavy industries, including petrochemical, refining, natural gas, manufacturing, mining, and transportation. The interrelated mix of products and services we provide enables our customers to increase machinery reliability, longevity, performance, safety, and environmental compliance.

The company is a multifaceted sales and service organization, with internal resources and capabilities that include engineering, manufacturing, assembly, and project management. We have created patented components, pioneered new applications and we enjoy close working relationships and extensive synergies with our principals (manufacturing partners) in product research and development.

www.tfhudgins.com

HJS Emission Technology GmbH & Co. KG, Menden, Germany

HJS Emission Technology GmbH & Co. KG is a family-owned, medium-sized company, established in 1976 and based in Menden, Federal Republic of Germany. Around 500 employees are engaged in the development, production, and marketing of modular systems for reducing pollutant emissions from combustion engines.

Above-average investment in research and development, technological excellence, and high performance as a specialist in the market have made the company a renowned address for state-of-the-art solutions in the field of exhaust gas aftertreatment. The focus of activities is on practical solutions for diesel for on-road and off-road applications. Solutions for gasoline engines are also part of the program.

HJS is an experienced, reliable system supplier and integrator for OEM and aftermarket customers. Customer proximity, flexibility, and the broad product portfolio as well as practical designs secure the excellent market position. The company has proven international partnerships. Competent representatives on site complement the successful concept. HJS is thus making a significant contribution to meeting environmental and climate targets in Germany and worldwide.

www.hjs.com

Stax Engineering Incorporated, Santa Barbara, CA

STAX Engineering, Inc., Santa Barbara, CA. STAX offers capture and control emission reduction solutions for terminal operators, container ships, auto carriers, and tankers. Based in Long Beach, California, our team is dedicated to helping achieve At-Berth CARB compliance without costly retrofitting. STAX offers barge-based, land-based, and mobile capture and control solutions as a service to terminal operators and fleets. STAX is the 2021 California Air Resource Board's grant recipient for technology advancement, ensuring our solutions meet expanding regulations today and in the future.

www.staxengineering.com

Addendum 2

Contact Addresses

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Addendum 3

Definitions and Abbreviations

After Sales Service	Periodic or as-required maintenance or repair of equipment by its manufacturer or supplier or service partner, during and after a warranty period.
City-Filter®	Diesel particulate filter (DPF®) made of sintered metal, for installation in passenger cars and light commercial vehicles (Germany: up to 3.5 t gross vehicle weight) with a filtration rate of up to 80%
CNG	**C**ompressed **N**atural **G**as is a fuel gas made of petrol which is mainly composed of methane (CH4). It is stored and distributed in hard containers at a pressure of 20–25 MPa (2,900–3,600 psi), usually in cylindrical or spherical shapes.
Commercial Vehicle	Vehicle designed for transporting passengers, goods and/or towing trailers. According to vehicle licensing agency regulations, this does not include passenger cars and motorcycles
CRT	**C**ontinuous **R**egeneration **T**echnology – Combination of a diesel oxidation catalytic converter (DOC) with a diesel particulate filter (DPF®) made of ceramic or sintered metal. Nitrogen dioxide (NO_2) produced by the catalyst regenerates the filter, i.e. continuously oxidises the particulate matter (soot) accumulated in the filter to carbon dioxide
CWMF	**C**atalyzed **W**ire **M**esh **F**ilter. Catalytic coated Partial Flow Particulate Filter out of wire mesh.
Datalogger	Electronic unit for recording, storing, displaying, and evaluating data relating to the exhaust-gas aftertreatment system
DEF Diesel Exhaust Fluid	Diesel exhaust fluid (DEF; also known as AUS 32 and marketed as AdBlue) is a liquid used to reduce the amount of air pollution created by a diesel engine. DEF is consumed in selective catalytic reduction (SCR) that lowers the concentration of nitrogen oxides (NOx) in the diesel exhaust emissions from a diesel engine.
DOC	**D**iesel **O**xidation **C**atalytic Converter – Technology for reducing the harmful HC and CO emissions in the exhaust gases of combustion engines
DPF®	**D**iesel **P**articulate **F**ilter. Registered trademark of HJS
Emission Class	Statutory limit for the emission of pollutants by combustion engines
eFuels	eFuel (abbreviation of electro fuel) refers to synthetic fuels produced from water and carbon dioxide (CO_2) using electricity. This process is known as power-to-fuel. The combustion of e-fuels basically produces just as much environmentally harmful exhaust as normal fuels. However, if the electricity used to generate the e-fuels is fed entirely from renewable sources and the necessary CO_2 is taken from the atmosphere or from biomass or industrial waste gases, e-fuels can be used to operate combustion engines in a climate-neutral manner.
eDOC	**e**lectrical **D**iesel **O**xidation **C**atalyst to support emission reduction efficiency under low operation temperature profiles
FTF	**F**low **T**hrough **F**ilter. Diesel particulate filter where partial exhaust emission will be bypassed without filtration. (See Partial Flow Filter)

GPF	**G**asoline **P**articulate **F**ilter are an emission aftertreatment technology based on diesel particulate filters (DPF), developed to control particulate emissions from gasoline direct injection (GDI) engines.
HDT	**H**eavy **D**uty **T**ruck, Class 7/8
ICI	**I**nternal **C**ombustion **E**ngine
Installer and Installation	Selected and trained staff or corporations for the installation of fixed or semi-fixed products, systems and complete with its accompanying assemblies, accessories and parts. Installation generally also includes provision of or connection to services (such as power and water supply) required to make the installed equipment ready for operation
LDT	**L**ight **D**uty **T**ruck, Class 4 and 6
Non-Road	Non-road mobile machinery, ships, locomotives, pieces of equipment and stationary applications that are not approved for operation on the road
OEM	**O**riginal **E**quipment **M**anufacturer of components and systems for new vehicles
On-Road	Vehicles that are licensed for road use. Have number plates (commercial vehicles, passenger cars, special vehicles). Also known in American English as "On-highway"
Passenger Car	According to vehicle licensing agency regulations, a vehicle used to transport people, with at least four wheels and a maximum of 8 seats excluding the driver's seat
Partial flow filter	Diesel particulate filter (DPF®) made of sintered metal where partial exhaust emission will be bypassed without filtration. The efficiency is adjusted to a defined level of filtration requirements and thresholds.
PEMS	Portable Emissions Measurement Systems, or PEMS, measure emissions from combustion engines as the vehicle or the equipment is being used, which allows real-world in-use testing.
Regeneration	Particulate-matter combustion process triggered by a chemical and/or thermal influence
Retrofit	Modernizations/re-equipping or repair with/of exhaust-gas after treatment systems and/or their components in vehicles, pieces of equipment or machinery already in service
RDE	The Real Driving Emissions (RDE) test measures the pollutants, such as NOx, emitted while driven on the road.
ROG	**R**eactive **O**rganic **G**as means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate.
SCR	**S**elective **C**atalytic **R**eduction – Reduction of NOx emissions from a diesel engine using a reduction agent and an SCR catalyst
SCRT®	**S**elective **C**atalytic **R**eduction **T**echnology System comprising an oxidation catalytic converter, diesel particulate filter and SCR catalytic converter. HJS one of the former co-owners of the patent

SMF®	**S**intered **M**etal **F**ilter Diesel particulate filter using sintered metal as substrate material. Registered trademark of HJS
SMF®-AR	**S**intered **M**etal **F**ilter with **A**utarkic **R**egeneration (self-regeneration), "thermoelectric regeneration". Regeneration process that uses a heating element, an additive dosing system and specially adapted ECU. Registered trademark of HJS
Telematic System (Remote Monitoring)	The HJS Telematics system is fully integrated with the HJS after treatment system. By use of the GPS tracking facility, vehicle position and speed as well as historical NOx data can be provided to compare NOx levels at specific emission hotspots
TM Thermal Management	Emission reduction technology to increase low engine operation temperatures.
TWC	A **t**hree-**w**ay **c**atalyst oxidizes exhaust gas pollutants - both hydrocarbons (HC) and carbon monoxide (CO) - and reduces nitrogen oxides (NOx) into the harmless components water (H^2O), nitrogen (N^2), and carbon dioxide (CO_2).

Disclaimer

07.10.2024