



VERT Report 2019/2020

Shaping the Future for Zero Impact
Combustion Engine Technology

The EU air-quality limit values are a **political compromise** and do **not reflect** the **necessary level of protection**, especially for vulnerable groups. The current **corona** pandemic is an example of **why more must be done for clean air** as quickly as possible. Particulate matter can cause or aggravate cancer, and respiratory and cardiovascular diseases.

According to current knowledge, these pre-existing conditions are associated with a **significantly increased risk of serious or fatal COVID-19 disease progression**. Studies carried out years ago on the SARS-CoV virus in China showed that in areas with **moderate or high air pollution**, the **risk of mortality** was **significantly increased**.

Jürgen Resch
Chairman

Deutsche Umwelthilfe e. V.

Dear VERT members and others it may concern,

For three decades, the international VERT Association has been consciously working to increase awareness of verified emission-reduction technologies, with a specific emphasis on the best available technology for carcinogenic combustion-generated nanoparticle applications and NOx minimization for diesel engines.

It is now widely accepted that all lung-penetrating emissions (irrespective of particle size) are a concern, not just in terms of diesel engines but also combustion engines in general and all applications.

VERT is, therefore, actively involved in several development projects, highlighting problems and various solutions, from small handheld equipment to large stationary & marine applications.

VERT introduced the particle number (PN) criterion for health reasons, which is now the basis of European and Chinese legislation.

VERT has successfully initiated the introduction of a New Periodic Testing Inspection (NPTI) system to ensure that products and technologies are not only functionable and efficient during test & validation but also during normal operation over time.

VERT has used the NPTI system to develop a scheme for checking in-use compliance, and it has also developed a validated system to ensure correct testing procedures, protocols and precise operational measuring equipment. In 2019, VERT completed its new strategy with a more holistic approach to zero environmental impact from combustion technology and mobility.



The journey of traditional diesel retrofitting will continue but in close conjunction with other emissions-related areas that can exploit the benefits of VERT's outstanding experience and globally applied know-how.

Yours sincerely,

Lars Christian Larsen,
VERT President

l.larsen@vert-dpf.eu



Landson Emission Technologies A/S

Clean Air on a Global Scale

VERT's success story started in the 1990s. Since then, the industry association has forged various partnerships with cities and environmental authorities, working to reduce air pollution from road traffic and non-road vehicles. These early projects in the last decade of the 20th century were the initial spark for many retrofit projects. All in

all, more than 1.7 million diesel particle filters (DPF) were installed by VERT members.

Currently, more than 100 million diesel engines are equipped with a filter that meets VERT criteria. Today, around the globe, nearly all types of vehicles and machines with internal combus-

Number of installed DPFs (retrofit) with VERT certification in thousands of systems / 2000–2020 (*NR = non-road)

| | 2001 - 2005 | | | 2006-2010 | | | 2011-2015 | | | 2016-2020 | | | Total |
|----------------|-------------|-------|-----|---------------------|-------|----|-----------|-------|-----|-----------|-------|-----|-------|
| | Bus | Truck | NR* | Bus | Truck | NR | Bus | Truck | NR | Bus | Truck | NR | |
| 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 |

tion engines are fitted with filters. The breakthrough for broad acceptance of VERT was our close cooperation with the European Commission on introduction of the particle number (PN) limit in the EURO 6/VI emission standard – a directive that has sustainably improved our quality of life.

VERT'S BREAKTHROUGH

EURO 6/VI is mandatory for all new diesel vehicles (passenger cars, light-duty and heavy-duty vehicles) in the European Union. Filters are also required for Stage V of the European NRMM (non-road mobile machinery) rules, thanks to the PN limit value. The European standards (including PN limits) have been adapted in many countries around the world, e.g., China.

CLEAN AIR DOES NOT COME FREE

Of course, VERT is still lobbying for use of the best available technology (BAT) in order to reduce combustion-generated nanoparticles. "Door openers" are usually created through contacts with decision-makers at scientific conferences. VERT presents a powerful argument at these conferences. Many VERT projects prove that the cost-benefit ratio of an emission upgrade is at least 1:40. This means that every euro spent on retrofitting saves 40 euros in the health system by avoiding treatment, e.g., for cancer, COPD, heart attacks, strokes, mental problems and other diseases. This benefit is a compelling argument for emission upgrade investments.

SAVE MONEY AND LIVES

Before embarking on any project, we carry out a careful analysis so that the best possible solutions and measures can be developed together with regional stakeholders. VERT companies provide support using proven, VERT-certified technology in supervised field



Dekati

trials. This approach has led to VERT projects around the globe (see table on the left-hand side and map on the following pages). Vehicles equipped with a DPF reduce airborne nanoparticles in cities (soot and metals) by up to 99.999%. Thus, PN concentrations in the exhaust gas of retrofitted diesel engines today are ten times lower than in ambient air on roads.

EHC Technik AB

Driving 100,000 km in a modern car means 0.05 g of soot reduction per km. This will lead to a 5-kg reduction in carcinogenic particles from one car only. Furthermore, HC and CO are practically eliminated, and there are no toxic side effects. According to VERT calculations, every year, more than 225 billion euros are saved worldwide in healthcare because cars with diesel particle filters reduce air pollution. In 2019, VERT celebrated its latest success: the capability to periodically check in-use particle filter compliance in diesel vehicles (see pages 16–17).

VERT believes that the next major step should be to make particle filters mandatory, not only for new machines but for all petrol vehicles. Diesel engines equipped with filters emit far fewer carcinogenic particles than petrol engines, especially DI (direct-injected) engines, so VERT suggests retrofits for older petrol vehicles. The association is also working on emission upgrades for vessels, handheld machines and emergency power generators (see pages 18–19).

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NEW STRATEGY

Finally, VERT has reviewed its strategy. A new, more comprehensive approach (see pages 8–9) will make the association attractive for additional groups of stakeholders. So, if you are not yet a member, consider joining our powerful group.

Canada

VERT has been running the DEEP (Diesel Engine Emission Project) since 2003 in partnership with Canadian mining companies, to promote health by reducing emissions, and this is now in force.

USA

Teaming up with regional and local clean air authorities, we have implemented several retrofit projects in the United States, e.g., retrofitting construction machines. VERT filters have been approved by the National Institute for Occupational Safety and Health (NIOSH) and the City of New York.

Switzerland

Switzerland has not only retrofitted all construction machines (50,000+ filters) but also fitted particle filters in buses, locomotives and ships ten years before other countries started doing so.

United Kingdom

VERT member companies retrofitted more than 4,000 buses in London, Birmingham and Manchester which were part of the public transportation system. Performance of the SCRT systems is controlled via telematic systems.

Germany

In Germany, several retrofit projects for construction machines have been carried out. For example, systems in Berlin, Bremen, Frankfurt, and Stuttgart have been equipped with DPFs. Germany also accepts VERT rules for its environmental zones.

Israel

Most railway lines in Israel are not electrified. Therefore, many diesel locomotives are still in use. VERT members retrofitted locomotives with modern DPFs in addition to retrofitting buses, trucks and waste collectors in Haifa and Tel Aviv based on VERT quality parameters.

China

China is widely known for the poor air quality in its megacities. It was one of the first countries to work on an international VERT project, supporting regional authorities with retrofit projects for city buses, transit buses and construction machines in Beijing, Nanjing and Xiamen. VERT elaborated the new PN-based legislation with the Chinese government.

South Korea

Relatively recently, VERT has started working with South Korea. The Korea Automobile Environmental Association (KAEA) and VERT agreed upon mutual recognition of its filter certificates. VERT members now have access to upcoming projects in Korea.

Mexico

Mexico City has had ties with VERT for a long time. Over the years, we have helped the regional administration of Mexico City improve air quality, e.g., through retrofitted DPF systems and stricter in-use compliance checks for cars using VERT particle number metrology 2017.

Colombia

Colombia retrofitted city buses in Bogotá with a DPF and implemented new emissions legislation under VERT guidance in 2012. It also recently introduced a law enforcing periodic technical inspections of diesel cars. This regulation is based on VERT's successful European NPPI project.

Chile

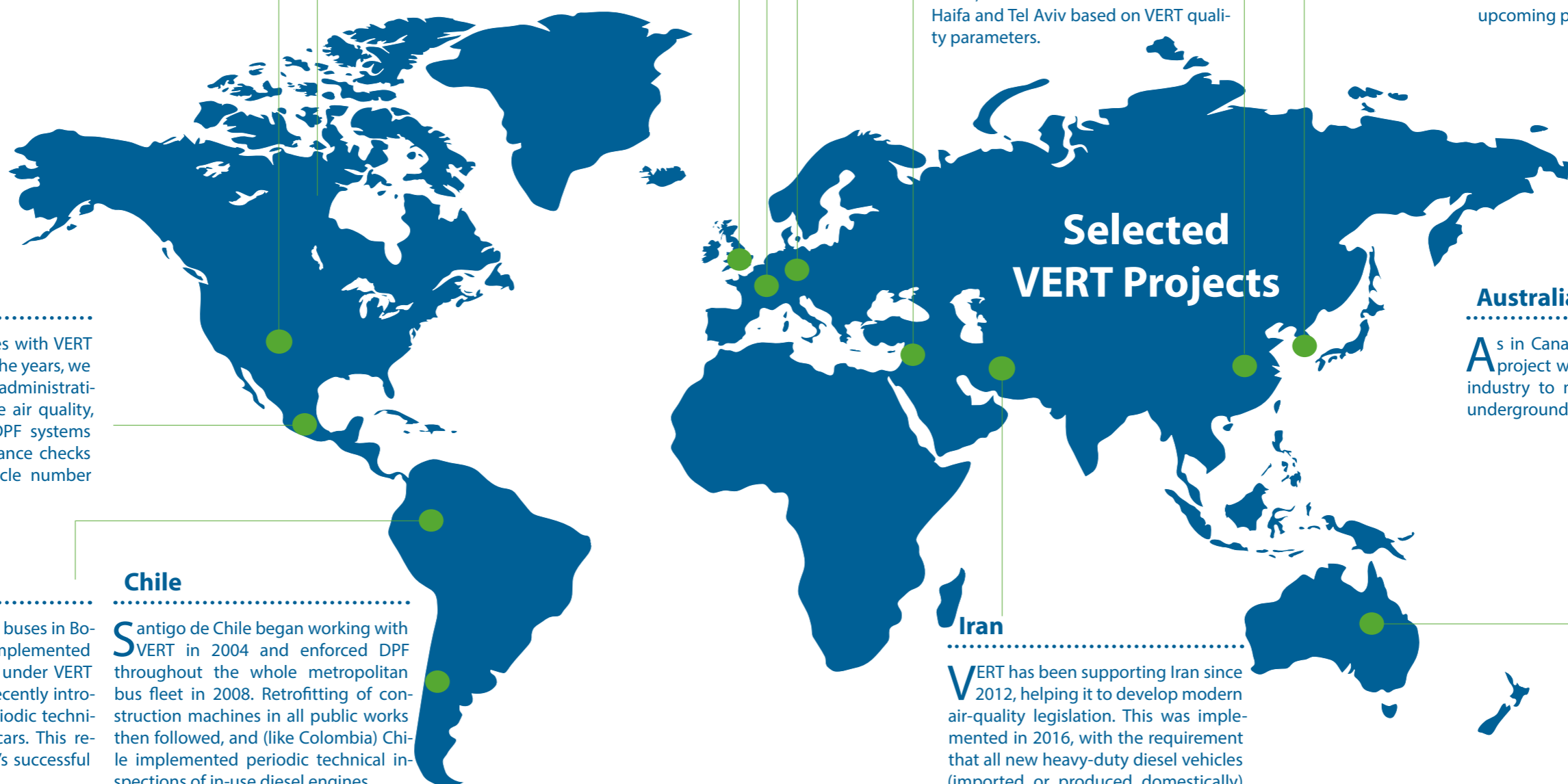
Santiago de Chile began working with VERT in 2004 and enforced DPF throughout the whole metropolitan bus fleet in 2008. Retrofitting of construction machines in all public works then followed, and (like Colombia) Chile implemented periodic technical inspections of in-use diesel engines.

Iran

VERT has been supporting Iran since 2012, helping it to develop modern air-quality legislation. This was implemented in 2016, with the requirement that all new heavy-duty diesel vehicles (imported or produced domestically) must have a VERT-qualified DPF.

Australia

As in Canada, VERT implemented a project with the Australian mining industry to minimize health risks for underground workers.



VERT'S Strategy

The international VERT Association has decided to broaden its focus to incorporate emerging markets like NOx abatement and particle filter retrofitting for marine/stationary machines and two-stroke handheld devices. Additionally, new synthetic fuels play an increasingly important role. The new approach is outlined in a strategy paper which describes the attractiveness of VERT for new members.

While diesel retrofitting remains an important part of any emission-control programme in many parts of the world, the focus of regulators in Europe and North America has shifted from diesel retrofitting to electrification. VERT considers this as one optional solution. VERT's focus is "zero-impact combustion engines", which includes:

- » Stricter NOx reduction under real driving conditions (RDE);
- » Electrified mobility;
- » Reduction of particle emissions from petrol engines, natural gas engine applications, handheld devices, marine and stationary applications;
- » Periodical inspection of in-use vehicles.

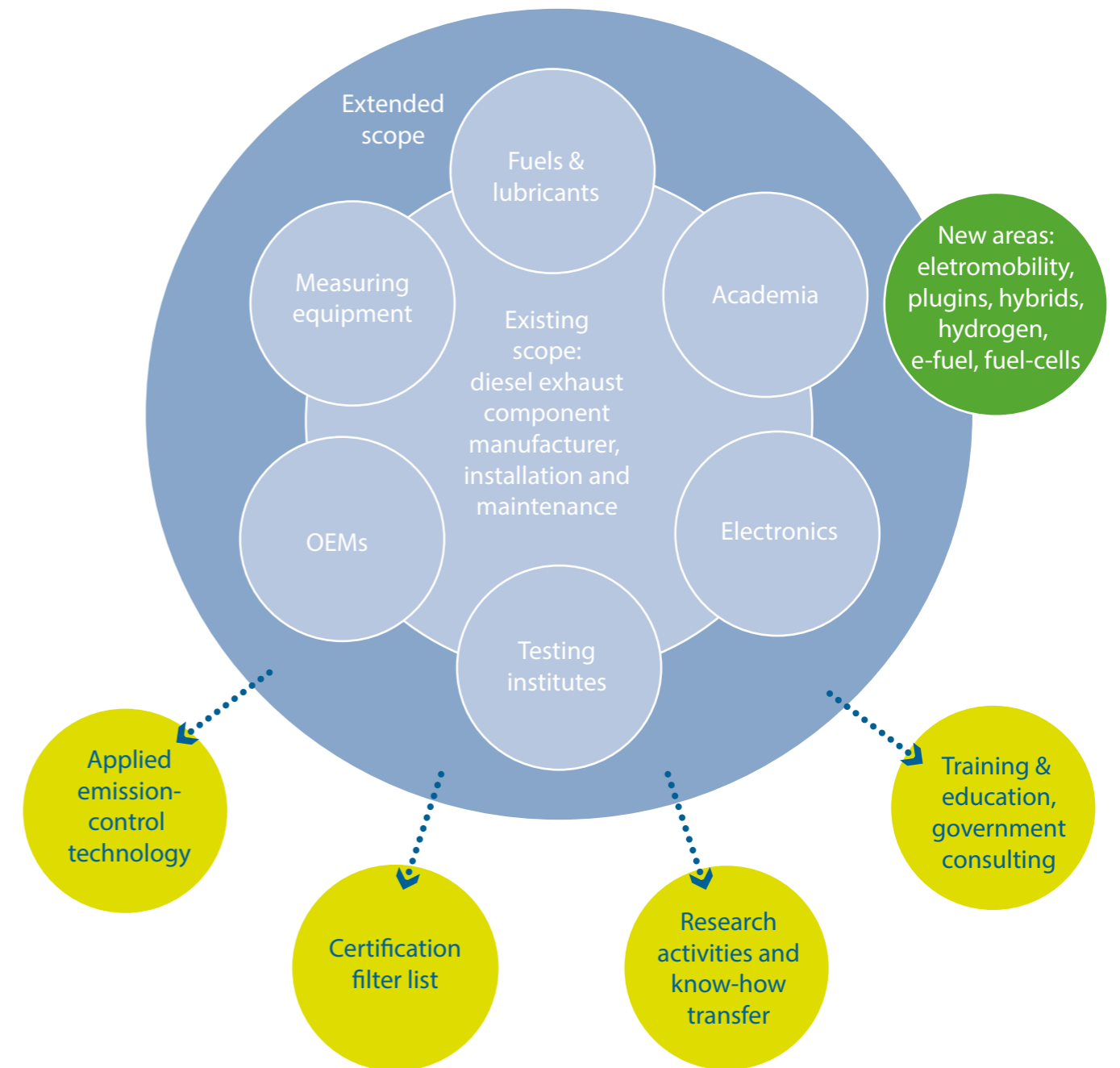
Globally, diesel engine retrofitting (PM, PN and NOx) still plays an important role in curbing urban emissions, particularly in areas where regulations are emerging, but it can only do so in conjunction with other activities such as infrastructure planning and electrified mobility. The currently laid-out clean air programmes in China, India, Iran and Latin America are good examples. European markets may continue to provide opportunities for retrofitting more efficient NOx-abatement solutions and

replacing previous retrofit installations, potentially driven by enforcement of in-use compliance and periodic inspection requirements such as NPTI. Adjacent to this is the supply of spare parts for light-duty, medium-duty, and heavy-duty on-road vehicles and potential replacement/retrofitting of three-way catalysts with a gasoline particle filter. Upgrading existing NOx-abatement installations will also provide some business in the future. New members can include the following: manufacturers/stakeholders in the gas- and petrol-engine application industry; measuring equipment manufacturers; design, testing & validation institutions; manufacturers of alternative fuels & lubricants; support infrastructure (installation and maintenance); and other organizations or parts of academia concerned with occupational health, environmental technologies and protection.

Stationary power generation, rail and smaller marine and river vessels will find value in membership.

Therefore, our goal is to expand the association in size and scope, to ensure a sustainable future and to continue playing a role in promoting not only verified emission-control technology for combustion engines but also alternative technologies.

Consultancy is therefore added since regulators in many areas are faced with the complexity of designing and implementing a clean air programme. They can benefit from VERT's unique expertise.



10 Facts

You should know About **VERT**

400,000 vehicles worldwide have been retrofitted with VERT certified DPF's

1 For the **St. Gotthard Tunnel** project, **SUVA** (the occupational health organization of Switzerland) cooperated with its partner organizations in Germany (**TBG**) and Austria (**AUVA**) to develop technical solutions for emission reduction. The project was called VERT (**V**erbesserung der **E**missionen von **R**ealmaschinen im **T**unnelbau – improvement of emissions of machines in tunnel construction). The name **VERT** was later adopted by **AKPF** (Arbeitskreis Partikelfilter-Hersteller), a working consortium providing technologies needed for the tunnel construction.

2 Soon, the project to certify particle filters was started. Since its foundation, 102 filter systems and substrates have been certified. VERT has criticized inefficient and harmful solutions like **DOCs** (diesel oxidation catalysts), open filters and systems that lead to the formation of secondary emissions like **dioxides**, **furans** and **nitro-PAH**.

3 Currently, the filter systems of 46 companies comply with **VERT rules**. Thus, they fulfil the highest global standards. Did you know that particles can be reduced by **up to 99.99%**? Diesel engines equipped with VERT-certified filters emit significantly fewer particles than are already present in ambient air. VERT claims that this is also the case with **on-road** and **off-road** systems, like locomotives and construction machinery.



4 The numbers are dramatic. Nine out of ten people worldwide breathe polluted air according to **WHO** findings. Up to seven million people die every year from poor air quality. Many of the world's **megacities exceed WHO guideline levels** for air quality more than **five times** over. To minimize the health burden, it is necessary to use the **best available technology (BAT)**. VERT has been advocating for BAT since its inception.

5 Particle mass is not a helpful criterion for air pollution. Scientists have detected that the **smallest particles** in the nm range are the **most dangerous** because ultrafine particles enter the human bloodstream via lung tissue and **reach nearly every part** of the **human body**. We, too, have proof that **many diseases** are associated with air pollution – not only lung cancer and COPD but also strokes, heart attacks and mental illnesses.

6 VERT has, therefore, been advocating for years that the **“particle number” (PN)** should be the decisive criterion for assessing air quality. VERT's advice has been heeded, and the **PN** is part of the current EURO VI/6 rules. We also believe that all standards must be harmonized adequately, since millions of super-lightweight particles do considerable harm but contribute little to mass-oriented values of **PM 10** and **PM 2.5**.

7 **NOx** and **NO2** abatement is very important for VERT members. They support European cities in minimizing nitrogen oxide levels. Modern SCR catalysts reduce **NOx by up to 99%**. This helps cities to comply with the European limit values. A bus fleet can be retrofitted in a short space of time, and several projects confirm this. **Emission upgrades** are currently the best method to avoid traffic bans and legal disputes about air pollution.

8 **Bus retrofitting** is also a **cost-effective** solution. A new electro bus costs about 700,000 euros. Retrofitting 50 to 60 older buses with a new DPF/SCRT system means the same investment. **London** is one of the pioneers of bus retrofitting, and the mayor, Sadiq Khan, has the right attitude, arguing, “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.” (www.london.gov.uk).

9 VERT advocates for **technology openness**. Society should not only have one option but should be able to draw upon different technologies like clean diesel, alternative fuels and electrification of mobility. Emission upgrades are often a more sustainable solution to minimize the levels of hazardous substances and to create cleaner air.

10 An integral part of **VERT's DNA** is leadership in innovation. Our new goal is a **zero-impact combustion engine**. With e-fuels, carbon-neutral emissions from combustion engines are possible. We advocate use of **optimal drive technology** for respective tasks. Electrified mobility is not always the best solution, and there is still a need for combustion technology. Diesel trucks are the workhorse of the economy.

VERT Technical Instructions

Another service that VERT provides by way of support for engineering, installation and maintenance is publication of short papers. These papers (which are updated regularly) are available as PDF files (free of charge) at www.vert-dpf.eu.

TECHNICAL INSTRUCTIONS

DPF Troubleshooting – Diagnosis and Remedy (TA-001/18)

What is Best Available Technology with respect to traffic-related emissions of ultrafine solid particles? (TA-002/18)

VERT testing of particle filter systems (TA-003/19)

VERT deNOx Certification (TA-004/19)

VERT approval criteria for particle filters (TA-005/18)

DPF onboard control & monitoring (TA-006/18)

Self-commitment of enterprises, manufacturing and retrofitting VERT certified emission control products like DPF, GPF, SCR (TA-009/18)

FBC dosing – Fuel Borne Catalysts (Additives) for DPF Regeneration (TA-010/19)

Local approval of DPF systems for option fit and retrofit of Diesel HDV (TA-011/18)

VERT certificates for emission reduction technology (TA-013/18)

Conditions and Procedures to Become VERT Accredited for EAS Certification Testing (TA-022/19)

TECHNICAL INFORMATION

Particle filters for all internal combustion engines (VI-001/18)

Meilensteine der Partikelfiltereinführung (VI-002/18)

Particle filter systems: Variability of solutions (VI-003 / 18)

BEST PRACTICE GUIDELINES

Best Practice Guidelines, Diesel Particle Filters, Systems for all Diesel Engines / Tips for Selection, Installation and Operation

PDF files are available in eight language versions: German, English, French, Hebrew, Mandarin, Persian, Polish and Spanish.

VIDEO REPORTS

VERT has published a documentary and several video reports about its conferences. These can be found at www.vert-dpf.eu (in the section relating to press & publications).

We particularly recommend the documentary “So that the air is good for breathing” (24:17 min). This film is available in English, German, Italian and Chinese.



VERT Filter List

VERT FILTER LIST

VERT-certified particle filter systems for combustion engines are published on the VERT filter list. The filter approval criteria are updated twice a year to reflect recent technological advances. The latest version of the filter list can be downloaded at www.vert-dpf.eu.

Below is a list of organizations that recognize the quality of VERT-tested particle filter systems. Some (*) require VERT certification expressis verbis in their legal documents, listed either in this VERT filter list or in the filter list of the Swiss Federal Office for the Environment (BAFU).

- » Austria: AUVA*, Tyrol, Vienna
- » Canada: DEEP*
- » Chile: MMT*
- » China: VECC*, BJ-EPB*, SWARC
- » Colombia: SDA Bogotá*
- » Denmark: DTI
- » England: LEZ London
- » France: CRAMIF*, INRS
- » Germany: BG BAU, UBA, TRGS* Berlin
- » Hong Kong: KBM, NWFB*
- » Iran: AQCC Tehran, DOE*
- » Israel: IMEP*
- » Italy: South Tyrol
- » Korea: KAEA
- » Mexico City: SEDEMA*
- » The Netherlands: VROM
- » New York: City* + Port*
- » Switzerland: BAFU*, SUVA*, ASTRA*

DATABASE

To designate machines fitted with approved filter systems, the VERT Association provides a quality label with a running number. All such fitted vehicles and equipment are registered in a publicly accessible database containing the technical data obtained during filter commissioning.

The manufacturer must perform spot checks on machines equipped with VERT-approved particle filter systems. The inspection results have to be submitted annually to the VERT Association. In order to be able to use the database, you need a (free) VERT account at www.vert-dpf.eu.



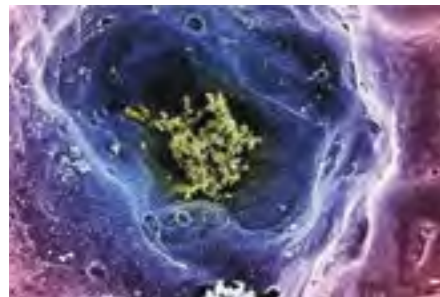
VERT Publications on Emission Reduction

VERT has been very active in publishing research papers in scientific journals as well as in professional journals. An up-to-date list of publications can be requested via email from VERT. Here is a list of the most recent papers:

- » Burtcher, Heinz, A New Periodic Technical Inspection for Particle Emissions of Vehicles, *Emission Control Science and Technology*, 5, 2019, 279-287, <https://doi.org/10.1007/s40825-019-00128-z>.
- » Czerwinski, Jan et al., Considerations of Periodical Technical Inspection of Vehicles with deNOx Systems, *SAE Technical Paper 2019-01-0744*, 2019, <https://doi.org/10.4271/2019-01-0744>.
- » Wyser, Max, In 125 Millionen Partikelfiltern steckt Bieler Know-how drin – weltweit, *Laudatio on Professor Jan Czerwinski on the occasion of his farewell as a professor of the Bern University of Applied Science*, 17 August 2019.
- » Mayer, Andreas, Report on the 23rd ETH Nanoparticles Conference, 17-20 June 2019.
- » Czerwinski, Jan et al., PN-Emissions of Gasoline Cars MPI and Potentials of GPF, *SAE Technical Paper 2018-01-0363*, 2018, <https://doi.org/10.4271/2018-01-0363>.
- » Muñoz, María et al., Effects of Four Prototype Gasoline Particle Filters (GPFs) on Nanoparticle and Genotoxic PAH Emissions of a Gasoline Direct Injection (GDI) Vehicle, *Environmental Science and Technology*, 2018, 52, 18, 10709-10718, <https://doi.org/10.1021/acs.est.8b03125>.
- » Mayer, Andreas, PN as Toxic Air Contaminant is by far underestimated while NO2 is overestimated – what about Toxicity Equivalent TEQ? Poster presented at the ETH Nanoparticle Conference, 18th-21st June 2018.
- » Heeb, Norbert et al., Impact of Low and High-Oxidation Diesel Particulate Filters on Genotoxic Exhaust Constituents, *Environmental Science and Technology*, 44/3, 2010, 1078-1084.
- » Mayer, Andreas et al., Metal-Oxide Particles in Combustion Engine Exhaust, *SAE Technical Paper 2010-01-0792*, 2010, <https://doi.org/10.4271/2010-01-0792>.

Additionally, three books have been published on the elimination of combustion-generated particles:

- » Mayer, Andreas et al., *Particle Filter Retrofit for All Diesel Engines*, Haus der Technik Fachbuch, Vol. 97, published by Priv-Doz. Dr.-Ing. Ulrich Brill, Expert-Verlag, Essen, Seventh Edition, 2008.
- » Mayer, Andreas et al., *Elimination of Engine Generated Particles Problems and Solutions*, Haus der Technik Fachbuch, Vol. 58, published by Priv-Doz. Dr.-Ing. Ulrich Brill, Expert-Verlag, Essen, First Edition, 2005.
- » Mayer, Andreas et al., *Minimierung der Partikelemissionen von Verbrennungsmotoren*, Haus der Technik Fachbuch, Vol. 36, published by Prof. Dr.-Ing. Eberhard Steinmetz, Expert-Verlag, Essen, First Edition, 2004.



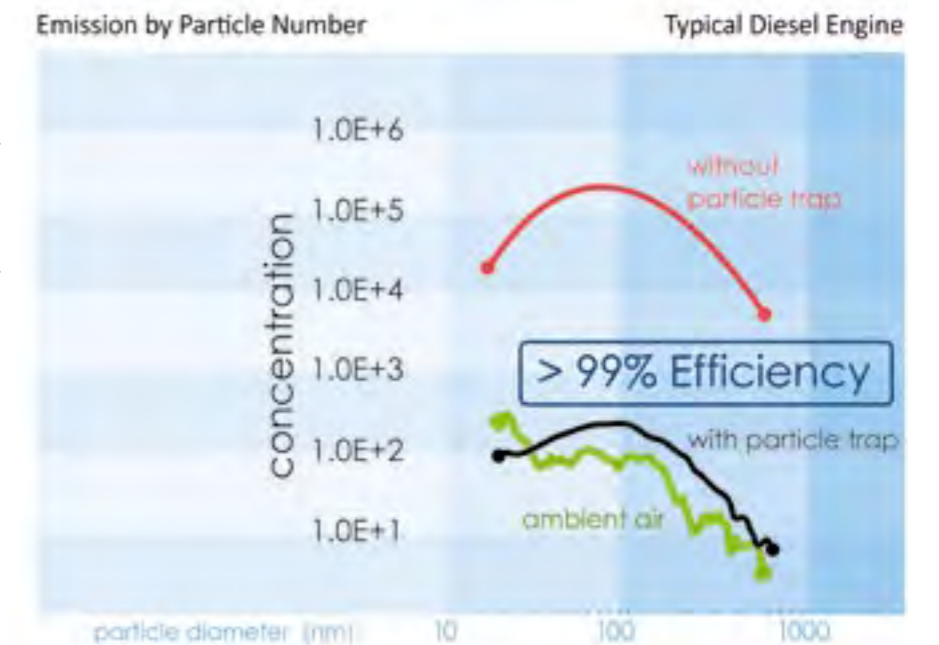
Ultrafine particles in the nm range penetrate through the lung tissue into all parts of the body.

VERT Public Affairs

Since its very beginning, VERT has been committed to the "best available technology" (BAT).

VERT has published several reports on this subject. The most important papers are listed below.

- » Gehr, Peter, Schildknecht, Jacques, *Abgaskontrolle und Gesundheit*, February 2020.
- » Mayer, Andreas, Best Available Technology BAT for the Elimination of Combustion Engine Related Ultrafine Solid Particles, paper for the Maggiore EU Commission, 9 pages, 2019.
- » Mayer, Andreas, Effects of Emission Aftertreatment Systems on Health, Economy and Global Warming – Is there an inherent vicious tradeoff?, paper for the Maggiore EU Commission, 11 pages, 2019.
- » Mayer, Andreas, A presentation for the expert meeting of the European Court of Auditors with respect to "EU Response to Dieselgate", October 2018.
- » Mayer, Andreas et al., Emissionsstabilität von Fahrzeugmotoren, Der einzig sichere Weg zur Emissionsstabilität bestverfügbarer Abgas-technologie ist die flächendeckende unabhängige periodische Kontrolle nach einem neuen Testprotokoll, Beitrag zur Sachverständigenanhörung des 5. PUA (18/8273, 8932) am 16. September 2016, Deutscher Bundestag, 5. Untersuchungsausschuss der 18. Wahlperiode, Ausschussdrucksache 18(31)88.



Diesel engines emit a huge number of particles in the nm range. Diesel exhaust can be cleaned with particle filters.

Why is NPTI so important?



A European working group, initiated by VERT in December 2016, has developed a new tamper-proof method to check the quality of exhaust after-treatment systems of diesel vehicles.

New devices for tailpipe measurements have been developed. The systems count the particle number (PN) of the exhaust gas flow in the tailpipe. Amongst others, the Netherlands, Germany, Belgium, and, as the first two non-European countries, Chile and Colombia have decided to introduce the new method.

In Germany, the so-called NPTI ("New Periodic Technical Inspection") will start on 1 January 2021. The PN value is considered to be much more reliable than the current OBD method (on-board

diagnosis) and the former (inaccurate) opacity test. OBD means that the test engineer plugs a device into the car. The diagnosis of the after-treatment system only sends an electronic message of failure modes to the display of the connected testing device. There is no exhaust assessment.

The new mobile measuring method makes it possible for the police to reliably check (on site), in less than a minute, whether the exhaust system is defective or has been tampered with. Control measurements of vehicles randomly selected from traffic, carried out by VERT together with the Netherlands

Organisation for Applied Scientific Research (TNO, Netherlands), the GOCA Institute (Belgium) and the Agency for Waste, Water, Energy and Air (AWEL, Switzerland), showed that up to 12% of Euro 5 and Euro 6 diesel vehicles did not have a correctly working particulate filter. The new portable measuring instruments were presented for the first time in Duebendorf near Zurich at the annual VERT Forum in March 2019.

So far, around ten manufacturers have developed devices in accordance with the new standard of the Dutch Metrology Institute (NMI), which came into force in June 2019. Garages and testing institutes can buy the devices to carry out the new method. Systems will cost around 5,000 to 8,000 euros.

12 %
of all diesel cars
drive with a defective DPF

Mr. Mayer, can you tell us why NPTI is so important?

Cars with a defective DPF will significantly exceed the emission limit. VERT measurements indicate that a new EURO VI car with a correctly working DPF will distribute virtually no particles. Tests showed that a car with a new DPF emitted about 200 particles per cubic centimetre. The ambient air had several thousands of particles per cubic centimetre. A diesel car with a defective DPF emitted about four million particles.

Why do so many DPFs fail?

DPFs, like any other car component, tend to malfunction over time (e.g., suffer mechanical damage). It is also fairly common for car owners to tamper with or remove DPF systems.

How did the NPTI initiative start?

In September 2016, we attended (on behalf of VERT) an expert hearing in the German parliament. Politicians were looking for an alternative to the OBD method. There were simply too many manipulations. The test was easy to tamper with and therefore useless.

Who were the members of the NPTI working group?

Several technical inspection institutes (e.g., TNO from the Netherlands and Spain, and also the German TUEV Sued) became members of the VERT initiative. The European Commission also supported us. The measuring device industry has been very active and has developed new systems.

How long will the test last and how much will consumers have to pay for it?

In Germany, the test can be carried out during regular inspections at testing facilities like the TUEV. It will only take half a minute, and the car owner will have to pay about 30 euros. This is a good investment in air quality.

What will happen in the case of a defect DPF?

The DPF has to be cleaned, repaired or replaced. VERT believes that in such instances, the car manufacturer should also be obliged to take action.



They currently guarantee the statutory emission level for five years or 160,000 kilometres. It will be interesting to see how the automotive industry reacts.

About Andreas Mayer

Dr. h. c. Andreas Mayer is globally recognized as a leading expert in the field of nanoparticles. Andreas Mayer has been VERT's Chief Scientific Officer since 1998.

a.mayer@vert-dpf.eu

Clean Vessels

Membrane Filter Project

Marine engines are responsible for as much particulate matter (PM) worldwide as all road traffic combined. It is time to change this. A new VERT project led by Thomas Lutz is looking for a filter solution to clean the exhaust of vessels.

According to comprehensive models, the effects of exhaust pollution from marine engines in terms of human health are proportionally smaller, since the exposure risk always has to take into account the exposure product and population, which is lower in the case of marine emissions. However, the major impact on melting of the polar ice caps and global warming in general must also be taken into account.



The technical challenges are considerable as the fuels used in the marine sector have a very high sulphur and ash content, which will be reduced in the foreseeable future only in coastal waters (so-called ECAs: emission-controlled areas). In addition, these engines (especially two-stroke engines) tolerate only low back pressure, deliver very moist soot (organic carbon (OC)/elementary carbon (EC) is high) and generally have low exhaust gas temperatures at full load, very often below 350° C. A further complicating factor is that the service intervals are very long; i.e., ash cleaning, as is usual with DPF, is excluded.

From a research project initiated by the ETH (1999–2001), we know some things about the character of these particles. They are surprisingly small (dangerous to health), which is due to the long burn-out time of these long-stroke, low-speed engines. They also contain large quantities of volatile aerosols (sticky), surprisingly few sulphates (as sulphur probably mainly

escapes as gas SO₂) and a very high proportion of non-soluble substances (ash), especially at full load. All in all, therefore, a picture emerges of an extremely important and urgent (but technically demanding) challenge for reasons of environmental protection, which we have taken up because we believe that this level of experience of filtration and catalysts is not available anywhere other than in the VERT network.

The new technical concept will involve so-called ceramic membrane filters instead of classic wall-flow filters, which have to be cleaned thermally/catalytically. Membrane filters, which are surface filters, can be cleaned pneumatically by back-flow pressure pulses. Additionally, the high proportion of sticky OC in exhaust gas has to be respected. A large part of this is highly volatile so cannot be filtered. They have to be removed by a foam oxidation catalyst, installed before the filter. The most important task, however, is design of the pressure pulse cleaning, a complex, three-dimensional, highly dynamic process with which we are familiar from an earlier project. We, therefore, know that only mathematical modelling will enable optimum design of these geometries.

The development consortium comprises marine engine manufacturers, as well as manufacturers of ceramic filters and catalysts. The project kicked off in September 2019 and has an official duration of two years. The overall costs are CHF 370,000.

About Thomas Lutz

Thomas Lutz is an engineer who has worked as a senior researcher at the University of Zurich (ETH). He advised the Swiss government on emission reduction. He is currently a member of the VERT Scientific Committee and is project manager of the VERT membrane project.

t.lutz@vert-dpf.eu

Handheld Devices

The VERT HaMaNet Project

Occupational health is a major concern. Millions of workers worldwide use handheld devices like chainsaws and hedge trimmers every day as part of their job. In one VERT project, we are considering how they can be protected better.

The HaMaNet project has been running since 2011, organized by Bern University of Applied Sciences (AFHB) at the request of the Suisse Federal Office for the Environment (BAFU). This is an international information exchange and a working group, which consists of various authorities (including BAFU and the European Commission's Joint Research Centre, JRC, Ispra/Italy), industry (manufacturers of handheld machines, lubes and fuels), consultants and academia. Several research activities have been inspired by this network.

The most important achievement is development of the Swiss norm SN 183161 for two-stroke fuels (alkylate) and fuel mixes, as well as bringing this norm into international use. As an essential effort to pave the way for consideration of new legislation and new limit values, the extensive emission testing undertaken at JRC in recent years should be mentioned. These efforts enabled the introduction of IUC and COP requirements. The most important technical conclusions are as follows:

- » The nanoaerosol from small two-stroke engines consists almost exclusively of lube oil high-boiling compounds (semisolids);
- » The amount and influence of ash content on PM/PN is insignificant;
- » HC-matrix and condensation effects have an important influence on PM/PN;

» Oxidation catalysts have significant reduction potential in terms of PM and PN;

» Use of the right lube oils, alkylate fuels and an active oxidation catalyst constitutes the best available technology.

Further objectives for improvements or regulations from the present standpoint include the following:

- » Lube oil quality
- » Oxidation catalyst quality
- » Potentials of secondary air
- » New legal limits
- » Improvements in personal protection

VERT is also concerned with the emission-reduction technologies of all small working machines in the interests of health, the environment and workers' protection.



About Prof. Jan Czerwinski

For over three decades, Jan Czerwinski was professor of mechanical engineering at Bern University of Applied Sciences. His main research field was emission reduction. He now serves as a member of the VERT Scientific Committee.

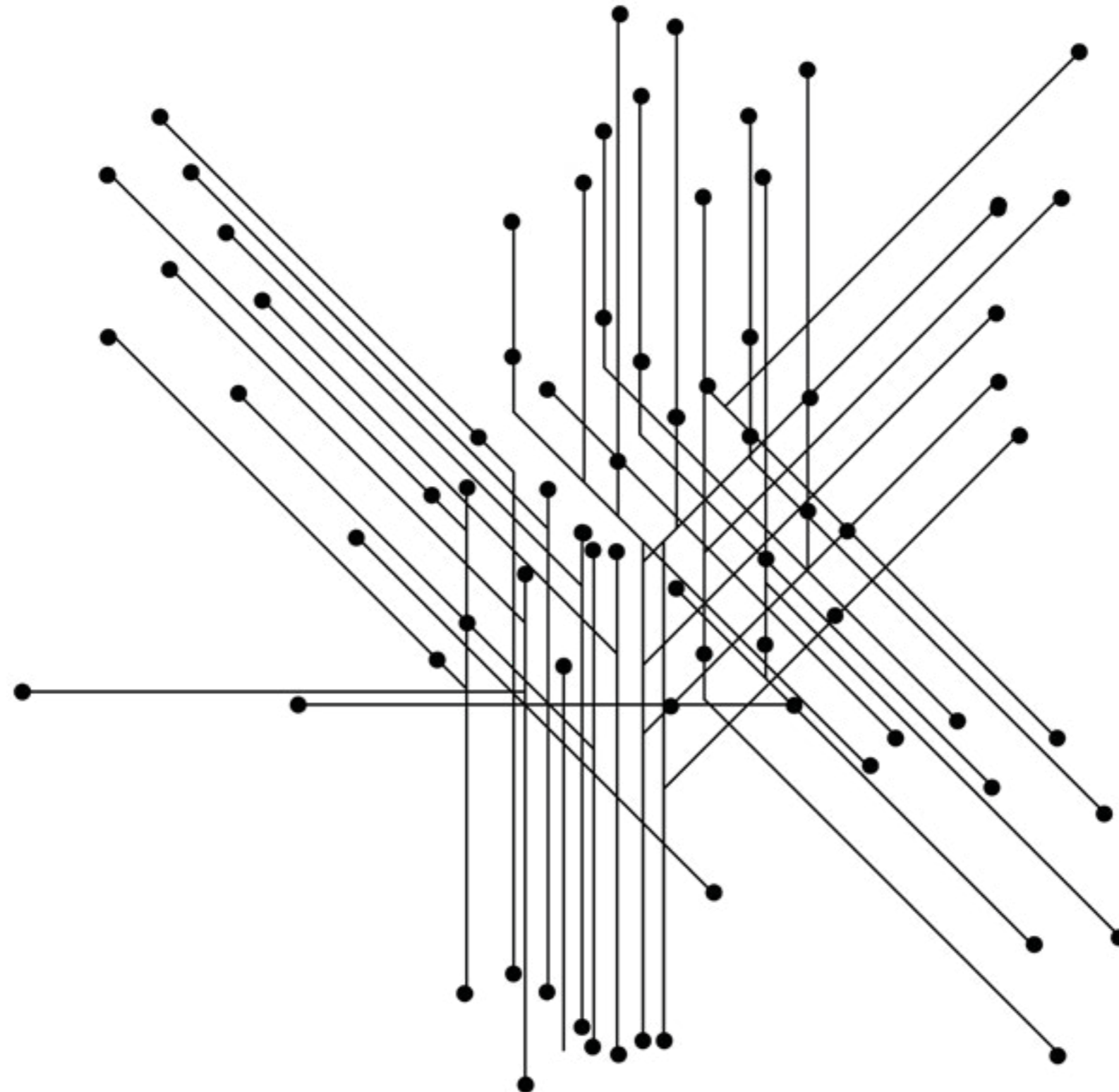
j.czerwinski@vert-dpf.eu

The VERT Network

1 VERT is part of a global network of scientists and practitioners. We work together with Bern University of Applied Sciences. **Prof. em. Jan Czerwinski** is one of the world's leading automotive scientists in the area of emission reduction. The **AHFB** lab has accredited engine-testing benches for type approval. VERT maintains close ties with his successor, **Prof. Danilo Engelmann**, as well as with **Prof. em. Heinz Burtscher** from the University of Applied Sciences Northwestern Switzerland.

2 We also have many partners in **Health Science**, e.g., the renowned Swiss researchers **Prof. Nino Künzli**, **Prof. em. Peter Gehr** and **Prof. Barbara Rothen-Rutishauser**. Scientists from the **Helmholtz Institute in Munich** and the Public Health Institute of **Duesseldorf University** give regular talks at our annual conferences.

3 VERT's network also includes the Swiss Federal Laboratories for Materials Science and Technology (**EMPA**) in Duebendorf near Zurich. EMPA scientist **Dr. Norbert Heeb** has contributed important findings in the field of exhaust chemistry. In March, the annual **VERT Forum** takes place at the EMPA. VERT also has close ties with Zurich University (**ETH**). In June, the annual **Nanoparticle Conference** takes place in the ETH building in Zurich.



4 VERT is highly respected for its emission-control expertise. The **European Commission** also appreciates our work. VERT has not only acted as an advisor for the rule framework and **implementation of Euro VI/6** but also for **NRMM Stage V** (non-road mobile machinery). Additionally, VERT works with the **Joint Research Centre (JRC)** in Ispra (Italy). The laboratory of the European Commission carries out a lot of research in close cooperation with VERT.

5 VERT keeps in close contact with overseas institutes. For several decades, we have worked with the **California Air Resource Board (CARB)** and the **US Environmental Protection Agency (EPA)**, both of whom are not only decisive authorities for emission control in the United States but also worldwide. We meet our colleagues from CARB and EPA every year at the Nanoparticle Conference in June.

6 VERT advises **occupational health** authorities, e.g., the Swiss Occupational Health Organization (**SUVA**). In Germany, VERT has close ties with the relevant employer's liability insurance association (**Berufsgenossenschaft**). Workplaces are required to fit diesel vehicles with filters under the provisions of **TRGS 554**, and these guidelines stipulate that such filters should comply with VERT standards.

7 VERT is regarded as a leading source of knowledge on exhaust after-treatment, and we are also recognized by **SAE International**. This association has more than 128,000 members, mostly engineers and other technical experts in the field of aerospace, automotive and commercial vehicle industries. Andreas Mayer and Professor Jan Czerwinski have been appointed as **SAE Fellows**. VERT representatives regularly give lectures at SAE events.

Conferences & Events



*One of VERT's most important values is our support for interdisciplinary scientific progress and training. VERT keeps these two topics on the public agenda with its annual **Nanoparticle Conference** at the **ETH in Zurich** (June), the **VERT Forum** at the **EMPA** (March) and the **VERT Project Day** in **Dresden** (November).*

ETH NPC CONFERENCE

The ETH Conference on combustion-generated nanoparticles (an annual event in June) serves as an interdisciplinary platform for expert discussions on a range of topics, including all aspects of nanoparticles freshly emitted from various sources, aged in ambient air; technical mitigation aspects; the impact of particles on health, the environment and climates; and particle legislation.

Lectures also cover a broad range of topics. Every year, about 400 participants from Europe, America, the Middle East and Asia discuss about 50 lectures and 90 poster presentations.

Scientists come from various disciplines, including medicine, public health, biology, chemistry and mechanical engineering.

Many attendees work in public administration, technical inspection institutes and traffic-control authorities. Lectures given at previous conferences can be found at www.nanoparticles.ch. This bibliography comprises more than 2,000 talks.

VERT FORUM

The second annual event is the VERT Forum. This takes place every year at the Swiss research institute (EMPA) in Duebendorf (near Zurich). About

120 international participants discuss the challenges of emission reduction, mainly from the perspective of practitioners.

At this one-day conference, best practice cases in emission reduction are presented. Participation at the Nanoparticle Conference and the VERT Forum is free.

VERT PROJECT DAY

Additionally, VERT members meet every year in November in Dresden to discuss ongoing technical developments in depth.

VERT Contributions at Conferences in 2019

Febr. 10–14: **Workshop**
Chennai, A. Mayer

March 14: **VERT Forum**
Duebendorf, T. Lutz, Prof. J. Czerwinski, A. Mayer et al.

April 2: **SAE Congress Emissions**
Detroit, Prof. J. Czerwinski, V. Hensel

April 8–9: **NPTI Workshop**
Arnheim, T. Lutz, A. Mayer

May 15–16: **EFCA**
Brussel, A. Mayer

May 15–17: **Transport and Air Pollution**
Thessaloniki, Prof. J. Czerwinski

June 13: **40 Years AFHB at the Berne University for Applied Science**
Biel, A. Mayer

June 18–20: **Nanoparticle Conference**
Zurich, A. Mayer, Prof. J. Czerwinski, Prof. D. Engelmann

June 25–26: **12th International Colloquium Fuels, TAE**
Osterfildern, Prof. D. Engelmann

June 26–27: **Integer Conference**
Munich, A. Mayer

July 1–5: **Workshop**
Chennai, A. Mayer

July 8–10: **PIC Conference**
Ann Arbor, V. Hensel, A. Mayer

July 10–11: **NDEC Partners Meeting**
Providence / Boston, V. Hensel

Sept. 6: **Membranfilter Project**
Biel, Th. Lutz, V. Hensel, A. Mayer

Oct. 7–11: **MDEC**
Toronto, A. Mayer

Oct. 14–17: **Nanoparticle Conference CALAC+**,
Mexico, V. Hensel, A. Mayer,

Nov. 6: **VERT Project Day**
Dresden

Nov. 7: **CITA-Workshop NPTI**
Brussels, A. Mayer

Nov. 12: **Marine Emissions**
University of Rostock, T. Lutz, A. Mayer

VERT Management Board

BOARD MEMBERS

Thomas Kaltwasser, Vice President
t.kaltwasser@vert-dpf.eu

Claas Löffler, Vice President
c.loeffler@vert-dpf.eu

Francois Jaussi, Finance, Liebherr
f.jaussi@vert-dpf.eu

Bernhard Kahlert, Puritech
b.kahlert@vert-dpf.eu

Frank Noack, CPK Automotive
f.noack@vert-dpf.eu

Jürgen Spielvogel, TSI
j.spielvogel@vert-dpf.eu

Michael Streichsbier, ESW Group
m.streichsbier@vert-dpf.eu

The VERT Management Board is elected by the general assembly. It usually takes place in March before the annual VERT Forum in Duebendorf/Switzerland.

The VERT Management Board represents the industry expertise of VERT. Board members are elected by the general assembly for two years. The current term of office lasts from 2019 until 2021.

Usually, three or four board meetings take place every year besides the general assembly, e.g., in Heidelberg, which is where VERT's German office is located.

Over the last year, the most important topic discussed at board meetings has been a modified strategy.

The board will be assisted by Lars Larsen (elected as VERT president by the general assembly for two years, until 2021) and CEO Volker Hensel.

Volker Hensel has served as CEO of VERT since 2014.



Lars Christian Larsen, President
l.larsen@vert-dpf.eu



Volker Hensel, CEO
v.hensel@vert-dpf.eu

VERT Certified Test Centres

In general, particle filter system test reports are only accepted from the VERT®-accredited test centres listed below. Accreditation according to ISO/IEC 17025 ext. SN 277206 is a prerequisite. These test results are the basis for granting certification according to the VERT® criteria. Additional supporting data can be submitted with requests for inclusion in the VERT® filter list. Such evidence will be taken into consideration when decisions are made about VERT® approval.

- » Laboratory for Exhaust Emissions Control (AFHB), Berne University of Applied Science, Prof. Danilo Engelmann, Gwerdstrasse 5, CH-2560 Nidau, Switzerland
- » EMPA Duebendorf, Dr. Norbert Heeb, Überlandstrasse 121, CH-8600 Duebendorf, Switzerland
- » AVL MTC Motortestcenter AB for VFT1, Sten Boman, P. O. Box 223, SE-13623 Haninge, Sweden
- » Southwest Research Institute for VFT1, Dr. Imad A. Khalek, 6220 Culebra Road, San Antonio, TX-78238, USA
- » TÜV Technische Überwachung Hessen GmbH for VFT1, VFT2, VFT3, Karsten Mathies, Werner-von-Siemens-Strasse 35, D-64319 Pfungst, Germany
- » VETC Xiamen Environment Protection Vehicle Emission Control Technology Center, Su Sheng, 5F, No.98 Jinlong Road, Jimei District, 361023 Xiamen, China



VERT Membership

VERT Members

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 EMINOX
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 TÜV SÜD AG / TÜV
 TUNAP Deutschland Vertriebs GmbH
 UMICORE
 Werkstatt Profi Programm GmbH
 Wuxi Weifu Lida Catalytic Converter

Currently, the VERT Association is based on more than 35 active members. These comprise international manufacturers of engines, testing devices, DPF and SCR systems, as well as substrate producers, chassis builders and others. Both personal and corporate membership is possible.

ADVANTAGES OF MEMBERSHIP

- » Technological exchange can take place between manufacturers of components, systems, engines, vehicles and measurement devices.
- » Member companies benefit from VERT technical projects, and they can use the results of these for their own product development.
- » Member companies are kept up-to-date with regard to international laws and regulations.
- » As the coordinator of projects on air pollution reduction in international cities and regions, VERT offers members attractive opportunities in the area of retrofitting.
- » As a member of VERT, engine and vehicle manufacturers have the advantage of being able to position themselves in emerging international markets at an early stage.
- » Members can participate in programmes through suitable forms of cooperation with exhaust after-treatment system manufacturers.
- » As a promoter of best available technology (BAT) and an emissions legislation consultant within the EU and emerging markets, VERT establishes

contacts between market participants, decision-makers and legislators at an early stage.

- » Members are, by default, considered to be BAT suppliers, and they can use VERT's registered trademark for their marketing.
- » Members can cooperate with one another and initiate projects together so that basic development costs can be shared between the companies involved, when applicable (or take advantage of external funding).
- » Members can attend exhibitions, workshops and conferences exclusively or at a reduced price.
- » Members can present their technologies at the well-established annual VERT Forum.
- » Collective marketing strategies in new exhaust after-treatment markets lead to reduced costs for individual companies.

VERT's Core Values

VERT is an association dedicated to the promotion of the best available technology for emission control.

VALUES

- » The core objective of VERT is minimization of the health burden caused by combustion engine emissions, and the elimination of ultrafine particles.
- » VERT stresses and recommends the application of particle number measurement against a pure particle mass count, as very light ultrafine particles are a major threat to health.
- » We set the highest quality standards by certifying emission-control technologies (VERT label) and publishing the VERT filter list.
- » VERT supports programmes for traffic pollution reduction all over the world, especially in megacities.

These core values are indispensable.

VERT AS A TRADEMARK

VERT® is a globally protected trademark. VERT® owns three world trademarks – VERT®, VERT® DPF and VERT® certified.

FINANCE

All VERT members have the same voting rights, irrespective of company size or annual sponsoring fees.

In 2019, 75% of VERT's annual revenue came from membership fees; 20% resulted from federal project funding; and 5% came from sponsorship.

The corporate membership fee is independent of corporate revenue. The fee for personal members is significantly lower.



LiqTech A/S



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Aemetstraße 3
CH-8166 Niederweningen
Switzerland

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