FVV PRIMEMOVERS. TECHNOLOGIES.

The FVV Transfer + Networking Event | Autumn 2022

Knowledge and technology transfer | New research programme

Science for a moving society

Science for a moving society

Knowledge and technology transfer

Climate neutrality and reducing emissions in energy conversion systems such as engines and turbines, as well as optimising hybrid powertrains and fuel cells, are some of the global challenges we face today. The pre-competitive Industrial Collective Research coordinated by FVV enables companies to work together to solve the research and technology problems that arise in relation to this, based on scientific findings.

At the Autumn Transfer + Networking Event 2022 in Würzburg on 6 October, FVV offered participants an opportunity to find out how current research projects are progressing, exchange results and expand their network.

The research results related to car and commercial vehicle emissions centred around the fundamentally new approach of ›zero-impact emissions‹, while those for ship powertrains focused on combustion and fuels.

Zero-impact emissions: immission and air pollution control // see complete project data from p. 20

PROJECT 1357 · Homogenisation Model SI Engines II
RESEARCH PRIORITY Development Tools
EXPERT GROUP Engines **APPLICATIONS** Cars and Light-duty Vehicles

PROJECT 1368 · Innovative HD Combustion System Design
RESEARCH PRIORITIES Emissions, Components
EXPERT GROUP Engines **APPLICATION** Trucks

The road to zero-impact vehicles

A ›zero-impact vehicle‹ is a vehicle whose emissions are so low that they do not have a measurable impact on the air quality and that thus meets the requirements for ›zero-impact emissions‹. As FVV has shown in fundamental studies, the basic technologies needed to implement a ZIV already exist. Further research activities will focus above all on tapping these technologies so that their potential can be used in the best possible way.

Less impact, more efficiency through optimum combustion

Daniel Ismail Mir from the Institute of Automotive Engineering (IFS) at the University of Stuttgart and Fabian Steeger from the Chair of Thermodynamics of Mobile Energy Conversion Systems (TME) at RWTH Aachen University presented results from FVV research project **›Homogenisation Model SI Engines II‹**. The starting point for this research project was the optimisation of emissions from SI engines with stoichiometric and homogeneous lean combustion. Homogeneous lean engine concepts are expected to gain market relevance in the future due to their great potential for increasing efficiency, combined with a reduction in CO_2 during fossil fuel use. Because the use of a conventional three-way catalyst to reduce NO_X emissions is not effective in lean operation, the reliable prediction of raw emissions is becoming increasingly important. The same goes for stoichiometric SI engines with strong hybridisation, as these often see the engine started when the exhaust gas aftertreatment system is cold and thus less effective. »The formation of NO_X and CO during fuel combustion in the engine depends largely on the local air-fuel mixture ratio and the temperature in the combusted mixture. Inhomogeneities in the mixture thus have a significant impact on emission formation – yet they are not sufficiently considered in current 0D/1D simulation approaches,« explained Steeger. Help is to come in the form of a phenomenological 0D/1D model to describe the fuel and temperature homogeneities in the combusted mixture, which is developed in the research project presented [FIGURE 1]. »The inhomogeneity model will then allow a more accurate prediction of the NO and CO raw emissions, which in turn will enable the exhaust gas aftertreatment components to be sized and coordinated more effectively,« said Mir.

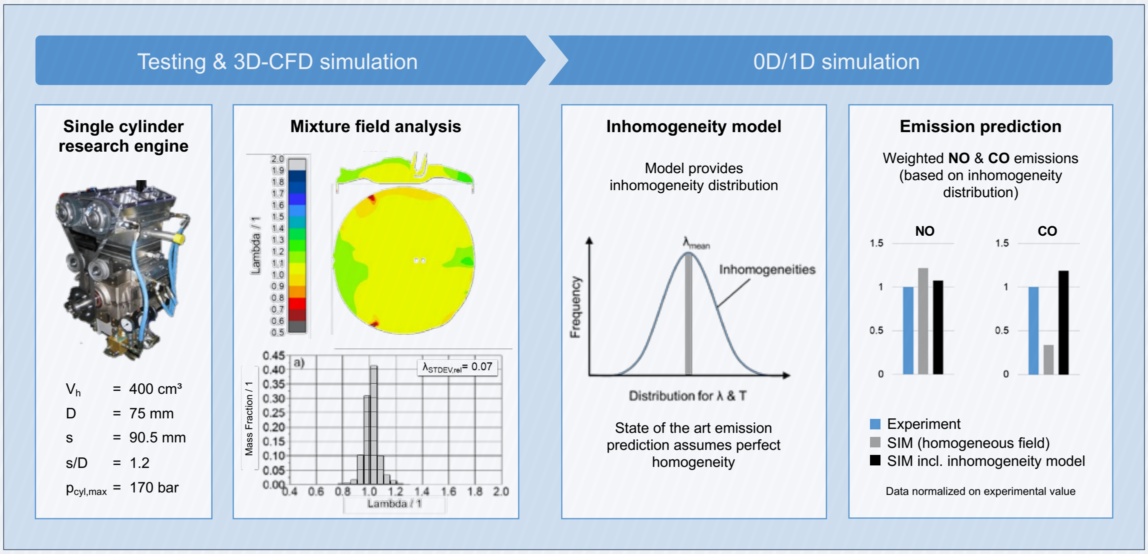

FIGURE 1

Schematic workflow of the inhomogeneity model development and visualisation of the improved emission prediction based on experimental measurement data from the single-cylinder research engine // IFS | TME

That makes the results a vital building block for the development of future ZIV. The research project is also highly significant from a business point of view, as the results can be directly incorporated into engine design and the development of system components, simulation software, development tools and engine control systems.

Pistons from the printer

In heavy-duty applications, engines using the diesel combustion process will continue to play a key role in the future. A balance must be found between low raw emissions and a high level of efficiency in their combustion development, taking alternative CO_2-neutral or CO_2-free fuels into account. This applies particularly to the conflicting aims regarding soot and NO_X emissions; this conflict can be resolved with various approaches such as optimised injection systems and the introduction of exhaust gas recovery and modern exhaust gas aftertreatment systems. If the system efficiency is to be enhanced further, however, the emission level and the efficiency of the combustion process itself need to be optimised. The piston geometry is a key aspect of this. Yet the options for designing the forged or cast pistons used today are significantly limited by the production process.

This is the starting point for research project **›Innovative HD Combustion System Design‹**. In their presentation, Jannis Reusch from the Institute for Simulation of reactive Thermo-Fluid Systems (STFS) at TU Darmstadt and Behrend Bode from the Institute for Product Development and

FIGURE 2

3D-printed heavy-duty piston with optimised bowl after first engine test // IPeG

Equipment Construction (IPeG), Leibniz University, Hanover, demonstrated how a piston with innovative piston bowl geometry and optimised cooling design was developed in the project and produced using an additive manufacturing process [FIGURE 2]. »Because design freedom is needed for the bowl and cooling channels, as well as fatigue strength even under high temperatures, the pistons are produced using selective laser beam melting,« said Bode.

The results gathered when modelling the heat flows and combustion using computational fluid dynamics (CFD) provided the starting point for optimising the bowl geometry. The piston bowl geometry was thus optimised iteratively before being applied to a piston design. »The optimisation's enormous potential for further reductions in consumption and emissions due to the printed piston bowl shape was demonstrated on the engine test stand,« said Reusch. The high degree of freedom in the design also allows the combustion to be tailored to alternative fuels, with joint optimisation of the piston geometry and injection system effective here. As the researchers also showed, hybrid production, in which only the piston bowl is printed and the rest is produced conventionally, also promises significantly lower production costs than a purely additive process. //

See also:
FVV Annual Magazine 2021
»Additive manufacturing«, pp. 64–69
→ www.fvv-net.de/en/

Zero-impact emissions: environmentally friendly marine propulsion systems // see complete project data from p. 20

PROJECT 1394 · Modelling of Pre-ignition in Gas Engines
RESEARCH PRIORITY Development Tools EXPERT GROUP Sustainable Powertrain Systems APPLICATION Marine Propulsion

PROJECT 1341 · Impact of New Silica-containing Fuels on Exhaust Gas Aftertreatment Components RESEARCH PRIORITY Emissions EXPERT GROUP Zero-impact Emissions APPLICATION Marine Propulsion

Zero-impact emissions technologies **for shipping**

According to information from the German Environment Agency (Umweltbundesamt – UBA), around 70 % of all goods worldwide – in relation to transport capacity, measured in tonne-kilometres – are currently transported by sea. Around half of global ship movements begin or end at a port in the EU. As such, the North and Baltic Seas are among the world's busiest shipping lanes in terms of both frequency and density. Zero-impact emissions technologies would therefore have a major effect in improving air quality, health and the climate – not only in EU waters, but in all the world's seas and oceans.

Modelling optimum engine operation strategies for ship powertrains of the future

Stricter emissions regulations on nitrogen oxide (NO_X) and sulphur oxide (SO_X) in shipping have caused the market share of gas and dual-fuel engines used as ship powertrains to increase continuously over recent years. One phenomenon that has a major impact on the range of operation for this kind of engine is pre-ignition, which is triggered by droplets of lubricating oil in the combustion chamber. Since extensive test campaigns are expensive, especially in large-scale engines, a fundamental understanding of this phenomenon and the options for predicting it based on simulations is of major economic significance across the sector.

FVV project **›Modelling of Pre-ignition in Gas Engines‹** thus employed quasidimensional process calculation to develop a phenomenological, predictive pre-ignition model that is to be used to optimise and design engine operation strategies, among other uses.

In Würzburg, Lukas Wißmann from the Institute of Automotive Engineering (IFS) and Patrick Albrecht from the Institute of Thermal and Fluid Engineering (ITFE) at the University of Applied Sciences and Arts Northwestern Switzerland (FHNW) gave an insight into the results of this close colla-

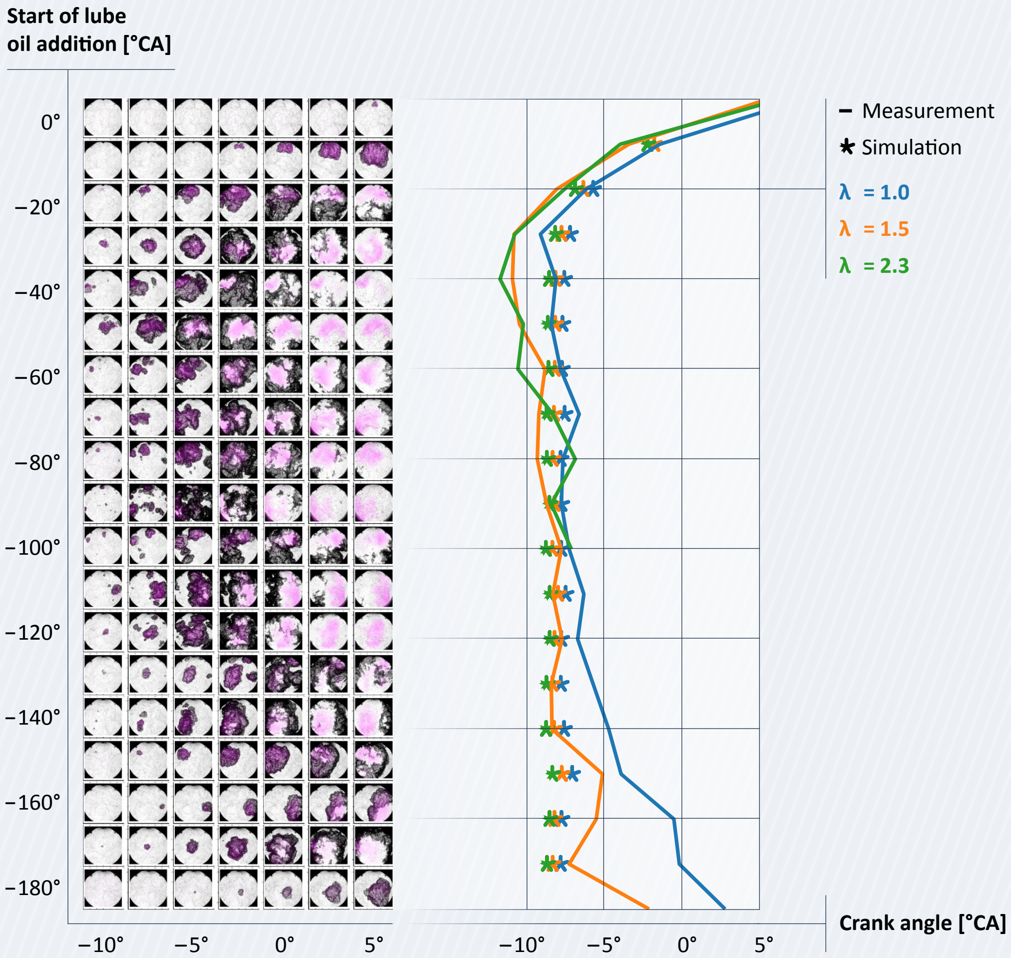

FIGURE 3

Optical measurement of lube oil induced pre-ignition at λ=1.5 for a varying start of addition [LEFT], and comparison of experimental results vs. simulation model [RIGHT] // ITFE-FHNW | IFS

boration between the two institutes. While engine testing was conducted at the ITFE, the IFS developed the modelling. The measurement data needed was determined at the ITFE using a highly flexible, optically accessible test specimen. »This allowed pre-ignition to be generated stably and measured under a wide range of conditions, such as varying mixture compositions, different pressures and temperatures, as well as different flow conditions, such as variable turbulence,« said Albrecht. In this case, the ITFE was able to investigate the influence of tiny quantities (≈0.08 mg) or even individual droplets of lubricating oil on pre-ignition in an ignitable methane-air mixture. The IFS then used this to develop the phenomenological pre-ignition model. »We found that pre-ignition does not occur without lubricating oil entering the combustion chamber, and that the evaporation of the lubricating oil droplets is key to the progress of the pre-ignition,« explained Wißmann. A droplet evaporation model was therefore also developed at the IFS to define the constraints for the reaction kinetics. The research team then used this to calculate the time of pre-ignition precisely **[FIGURE 3]**. Because the model is based purely on physical assumptions, no further parameters for specific coordination need to be recorded for the predictions, unlike when other approaches are used. This makes it easier to apply the model to future engine developments and allows immediate increases in efficiency in the development process.

Low-sulphur fuels are good for the air quality in coastal waters, but their silicon content carries great risks for catalysts and exhaust gas sensors

The Paris Climate Agreement of 2015 and the 2018 United Nations Climate Change Conference in Katowice sent a clear message that the future of maritime shipping lies in the use of low-sulphur fuels. International agreements stipulate a gradual reduction in the sulphur content of shipping fuels to 0.5 % from 1 January 2020. In the SO_x Emission Control Areas (SECA) in the North and Baltic Seas, along the North American coast and in the US Caribbean, this reduction goes even further: since the start of 2015, the threshold in the SECA has been reduced to 0.10 % in a further step.

The researchers in the FVV project **›Impact of New Silica-containing Fuels on Exhaust Gas Aftertreatment Components‹** examined problems with low-sulphur fuels for ship engines. In order to reduce sulphur emissions, only fuels with a sulphur content of no more than 0.1 % can be used in defined environmental zones (SECAs) in ships without exhaust gas desulphurisation. Ultra-low-sulphur fuel oils (ULSFO) are generally used. These fuels are often blends that contain residues from the refinement process and distillate fractions in order to meet the statutory sulphur requirements. Since they were introduced, however, some SCR catalysts have been returned because they had a thin layer of silicon dioxide on the catalyst surface. As a result, the catalyst activity fell dramatically after just 8,000 hours of engine operation in some cases.

Dr Marit Kolb from the Institute of Environmental and Sustainable Chemistry (IÖNC) at TU Braunschweig and Lars Wesemann from the Institute for Internal Combustion Engines (ivb) at TU Braunschweig presented the findings on the phenomenon from their research. The project examined various shipping fuels for contamination with different silicon compounds and determined the

FIGURE 4

Analytical results marine fuels: contents of total silicon and low molecular weight siloxanes ($\sum D_4, D_5, D_6, L_4, L_5$) in marine fuel samples [ABOVE] and experimental results fuel burner test bench: SCR catalyst deactivation by low sulphur fuels (0.1 % S) doped with organic silicon compounds [BELOW] // IÖNC | ivb effects these compounds have on SCR catalysts [FIGURE 4]. »In the chemical analysis of 64 shipping fuels, we were able to detect siloxanes – chemical compounds containing silicon – in 30 % of the samples, in concentrations between 0.052 and 40 mg/l. We did not find any correlation between the siloxane concentration and the total silicon content of the fuel,« reported Kolb. On the fuel burner test stand, the siloxane-doped fuels caused fast deactivation of the catalyst due to the formation of a silicon dioxide layer on the surface of the monolith. »Even small silicon concentrations in the fuel caused a measurable loss in SCR activity. This process appears to occur regardless of the chemical structure of the organic silicon compound. Only the total concentration of the organic silicon compounds in the fuel affects the level of catalyst deactivation,« said Wesemann. The fall in SCR activity varied between different fuels. »Organic silicon compounds led to greater deactivation in the combustion of distillate fuels than that of fuels containing residue oil,« explained Wesemann. The key measures to prevent silicon dioxide deposits on the catalyst remain as follows: using fuels without organosilicon compounds as defoamers in refinement; sizing the catalysts appropriately to increase tolerance to this kind of catalyst poisoning; or defining mandatory global limits for the concentration of organic silicon compounds in ULSFO. The chemical analytics required for this was developed in the project. //

Around **300** participants from industry and science joined in lively discussions

A total of **31 projects** on scientific and technological foundations for climate neutrality and zero-impact emissions from sustainable energy conversion systems were presented

On **30 March 2023** we will meet again in Würzburg for the next FVV Transfer + Networking Event

Science for a moving society

Our task is to keep the **future open**

Around 300 attendees from companies, research bodies and associations came together in Würzburg to learn about the latest results of ongoing and recently completed FVV research projects. Their enormous interest and the lively discussions that followed the presentations showed how hugely important the research content presented is to the development of economical and clean energy and powertrain systems. The pragmatic, neutral approach taken in FVV research, which focuses on a technology's potential to solve problems, is particularly highly valued.

In order to meet the demands of research in the future, FVV has restructured its research portfolio and research groups over recent months. The pre-competitive Industrial Collective Research organised by FVV thus provides the foundation for the development of even more environmentally friendly and resource-saving engines, hybrid powertrains, turbines, compressors and fuel cells.

The success of this year's FVV Autumn Transfer + Networking Event shows that live conferences are still a key medium for exchanging information and ideas and expanding the scientific network. FVV's next transfer event is planned from 29 to 31 March 2023, once again in Würzburg.

See also:
The FVV Transfer + Networking Event | Spring 2023
→ www.fvv-net.de/en/

Future fuels and energy sources: transformation of the European mobility sector // see complete project data from p. 20

PROJECT 1452 · FVV Fuels Studies · Part IVb
RESEARCH PRIORITY Orientation study **EXPERT GROUPS** Board, Sustainable Power Systems **APPLICATIONS** Cars, Light, Medium and Heavy-duty Vehicles

Keynote: how quickly can we be **sustainable?**

Diversity is also essential in science, so that we can not only think openly about the future, but also enable an efficient and sustainable future. A critical view must be taken of banning specific technologies, as this is more likely to delay than accelerate the transition to CO_2-neutral powertrains. Another FVV study on the fuels of the future has analysed how greenhouse gas neutrality can be achieved as quickly as possible in the European transport sector, taking the ramp-up potential of individual technology pathways into account.

FVV gives insights into sustainable pathways to climate neutral mobility

The European automotive industry is facing many challenges – rising energy prices, shortages of raw materials and interrupted supply chains to name just a few. And the future is more than uncertain. Given these conditions, is it really a good idea to put all our eggs in one basket? Would greater diversification not produce benefits in terms of the sustainability and competitiveness of future powertrain technologies?

These were the questions examined in an extensive study entitled ›**Transformation of Mobility to the GHG-neutral Post-fossil Age**‹, which was published in October 2021. The results of a supplementary study were presented at FVV's Autumn Meeting in Würzburg.

It contains four key features:

- Greater focus on the road sector
- Addition of new combinations of powertrains and greenhouse gas-neutral energy carriers (plug-in hybrid electric vehicles and methanol-to-gasoline (petrol) drop-in fuel)
- Consideration of the technical potential for expansion of non-fossil transformation pathways for European road transport (EU27+UK)
- Examination of a technology mix that provides optimum support for the transition to greenhouse gas neutrality

In particular, the supplementary study takes into consideration the achievable ramp-ups of new vehicle technologies, the power generation and distribution infrastructure, and the raw material supply on a quantitative basis. The ramp-up potential of non-fossil transformation pathways is highly significant in order to adhere to the remaining theoretical greenhouse gas budget that applies in Europe in line with the Paris climate goals.

The new model-based optimisation and analysis framework applied in this study explicitly looks at the question of how the cumulative greenhouse gas emissions in the road sector in the EU27+UK could be minimised. The results show that a mix of carbon-neutral transformation pathways can considerably accelerate the transition to greenhouse gas neutrality compared to scenarios with a single technology option. A technology mix thus significantly reduces the cumulative greenhouse gas emissions over time.

The results can be summarised as follows:

- **A mix of carbon-neutral energy carrier/powertrain pathways can speed up the transition to GHG neutrality for the EU27+UK road sector:** The study shows that all carbon-neutral pathways face bottlenecks of various kinds, constraining the maximal deployment rate for each individual technology. A mix of technologies can, therefore, accelerate the penetration of carbon-neutral energy carrier and powertrain technology pathways (›technology pathways‹) significantly [FIGURE 5+6]. A combination of technology pathways could thereby reduce cumulated GHG emissions significantly: For example, a scenario focussing on BEV (with domestic energy sourcing) as the only GHG-neutral technology pathway available yields to 39 % higher cumulated GHG emissions by 2050 compared to a mix of GHG-neutral technology pathways. This further translates in the single technology BEV pathyway only achieving a 76 % defossilisation rate of the EU27+UK vehicle stock until 2050 – while the GHG optimised mixed technology scenario allows to achieve carbon-neutrality (100 % defossolisation rate) by the year 2039 already.

- **The decisive factor to minimise GHG emissions is the fastest possible departure from fossil fuels – infrastructure and material bottlenecks need to be addressed quickly:** In order to minimise GHG emissions in the EU27+UK road sector infrastructure and material bottlenecks need to be addressed quickly. This holds in particular for the necessary scale-up of infrastructure and material availability across technologies.

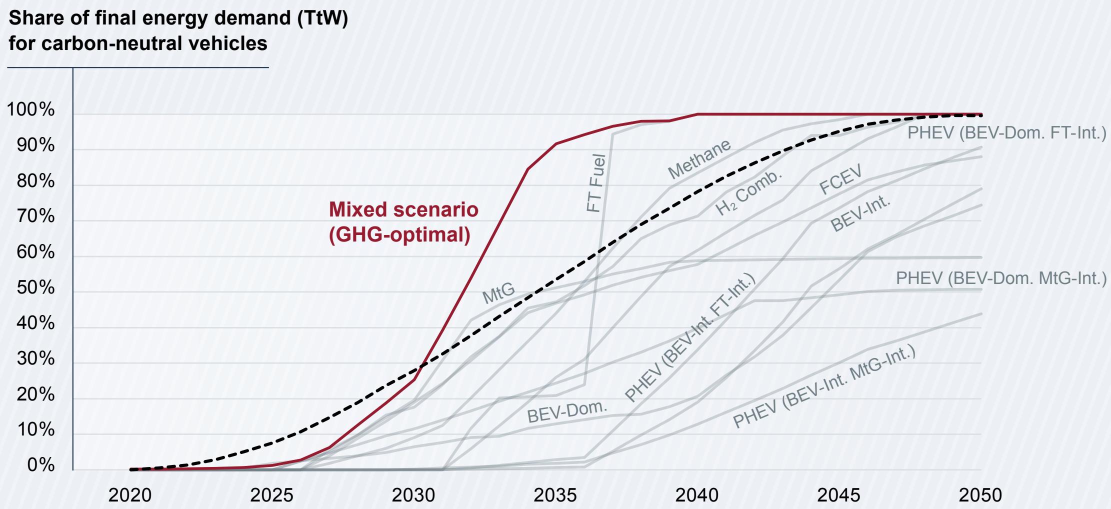

FIGURE 5

Share of carbon-neutral TtW energy demand in GHG-optimal mixed technologies scenario; single technology scenarios greyed out // Frontier Economics

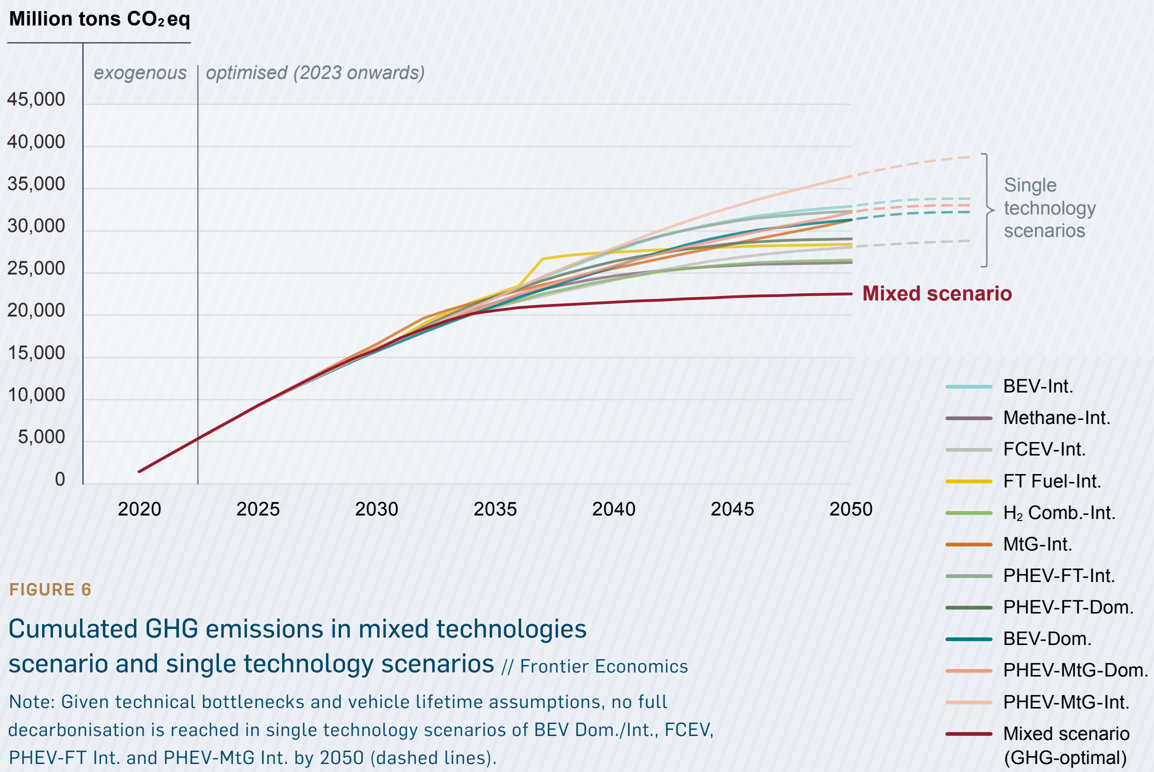

FIGURE 6

Cumulated GHG emissions in mixed technologies scenario and single technology scenarios // Frontier Economics

Note: Given technical bottlenecks and vehicle lifetime assumptions, no full decarbonisation is reached in single technology scenarios of BEV Dom./Int., FCEV, PHEV-FT Int. and PHEV-MtG Int. by 2050 (dashed lines).

- **E-fuels provide a unique technology option to carbon-neutrally operate the existing fleet:** Backward compatible energy carriers such as e-gasoline and e-diesel (e. g. via Methanol-to-Gasoline and Fischer-Tropsch pathways) allow a quick defossilisation of the existing vehicle fleet once they become available at large scale. Despite long lead times for setting up synthesis plants, they can, therefore, accelerate overall GHG reductions.

- **Banning ICE vehicles from 2035 would lead to higher GHG emissions than necessary:** While a defossilisation of the EU27+UK road sector could also be achieved without ICE vehicles, this would in turn increase cumulated emissions and cumulated total costs, as it further reinforces dependencies on critical technical bottlenecks and limits the option to accelerate further defossilisation through compatible synthetic energy carriers (e-gasoline, e-diesel) to any existing ICE vehicle fleet.[1]

- **Shifting the heavy-duty segment towards carbon-neutral technology pathways is a big lever to enable significant GHG emission savings:** While heavy-duty vehicles only make up for approx. 2 % of the EU27+UK vehicle stock, they account for approx. 45 % of today's overall total fuel consumption of the European road sector.[2] Therefore, they hold an enormous potential for GHG emission savings. //

[1] We note that in the ICE ban scenarios considered in this study it is still possible to operate the existing legacy fleet with e-fuels until the end of their lifetime, see Section 6.2. In contrast, new vehicles registered after an effective ICE ban (i. e. in 2035) cannot be operated with e-fuels and therefore rely on technology pathways excluding internal combustion engines. While this approach may seem unrealistic under the current EU ›Fit for 55‹ policy approach, it is consistent with our general assumption in this study assuming ideal financial and legal conditions for all powertrain technologies available.

[2] Assessment by Frontier Economics based on ACEA data. See ACEA (2022a), ›Vehicles in use Europe 2022‹, https://www.acea.auto/files/ACEA-report-vehicles-in-use-europe-2022.pdf (last accessed: 08.09.2022).

See also:
Further information in the science story »How quickly can we be sustainable?«
→ www.fvv-net.de/en/

DR.-ING. ULRICH KRAMER

Our modelling approach ventures a look into the future and shows what is possible from a technological point of view and what would be reasonable with respect to the ultimate goal. However, it is not a forecast. // FVV

Proceedings R 603
The FVV Transfer + Networking Event | Autumn 2022

→ www.themis-wissen.de

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1308	› **Bidirectional Aeromechanical Coupling I:** Analysis of the effect of nonlinear aeroelastic interactions on the forced vibrations of coupled turbine blades › DFG, FVV	› Prof. Dr.-Ing. Malte Krack (ILA, Universität Stuttgart) Prof. Dr.-Ing. Reinhard Mönig (DLR-AT) › Dr. Andreas Hartung (MTU Aero Engines AG)	› R 603 (pp. 801–821)
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1368	› **Innovative HD Combustion System Design:** 3D printing for innovative heavy-duty diesel combustion system design › FVV	› Prof. Dr. sc. techn. Thomas Koch (IFKM, KIT Karlsruhe) Prof. Roland Lachmayer (IPEK, Leibniz Universität Hannover) Prof. Dr.-Ing. Christian Hasse (STFS, TU Darmstadt) › Priv.-Doz. Dr.-Ing. habil. Reza Rezaei (IAV GmbH)	› R603 (pp. 365–399)
1369	› **Interference Noise in the Vehicle Compartment with Electrified Drives:** Characteristics for quantifying the annoyance of interference noise in the compartment of vehicles with an electric drive system › FVV	› Prof. Dr.-Ing. Stefan Pischinger (tme, RWTH Aachen) Prof. Dr. Jesko Verhey (EXA, OVGU Magdeburg) › Dr. Stefan Heuer (MAN Truck & Bus SE)	› R603 (pp. 494–528)
1370	› **Fast Knocking Prediction for Gasoline Engines:** Fast and robust simulation tool for knocking prediction of gasoline engines › FVV	› Prof. Dr.-Ing. Stefan Pischinger (tme, RWTH Aachen) Prof. Dr.-Ing. Michael Bargende (IFS, Universität Stuttgart) › Dr.-Ing. Michael Fischer (Tenneco GmbH)	› R603 (pp. 241–277) › H1296 (2022)
1373	› **Dynamics of TC Rotors with Coupled Bearings:** Transient simulation of the non-linear dynamics of exhaust gas turbocharger rotors, taking into account the interactions of journal and thrust bearings via the oil supply system › BMWK/AiF	› Jun.-Prof. Dr.-Ing. Elmar Woschke (IFME-FSK, OVGU Magdeburg) Prof. Dr.-Ing. habil. Jens Strackeljan (IFME, OVGU Magdeburg) › Dipl.-Ing. Thomas Klimpel (Turbo Systems Switzerland Ltd.)	› R603 (pp. 822–853) › H1292 (2022)

NO	› TITLE › FUNDING ORGANISATION	› RTD PERFORMERS › PROJECT COORDINATION	› PROCEEDINGS › FINAL REPORT
1376	› **Rotordynamic Casing Models and Model Update:** Development of nonlinear casing models and multi-step model updating strategies for improved rotordynamic models › BMWK/AiF	› Prof. Dr.-Ing. Jörg Seume (TFD, Leibniz Universität Hannover) Prof. Dr.-Ing. Jörg Wallaschek (IDS, Leibniz Universität Hannover) › Dr.-Ing. Joachim Schmied (Delta JS AG)	› R 603 (pp. 854–888) › H 1317 (2022)
1380	› **Probabilistic Lifetime Model Comparison – Creep-Fatigue:** Application and comparison of lifetime models for analysing high-temperature components under creep-fatigue loading by utilising sophisticated probabilstic methods › AVIF	› Prof. Dr. Hanno Gottschalk (Stochastik, Universität Wuppertal) Prof. Dr.-Ing. Matthias Oechsner (MPA-IfW, TU Darmstadt) › Dipl.-Ing. Henning Almstedt (Siemens Energy Global GmbH & Co. KG)	› R 603 (pp. 628–660)
1385	› **T/C for Lean Burn Concepts:** Single stage charging system for SI-engines operated with $\lambda = 2$ in the range of the WLTC › FVV	› Prof. Dr.-Ing. Peter Eilts (ivb, TU Braunschweig) Prof. Dr.-Ing. Jörg Seume (TFD, TU Braunschweig) › Dipl.-Ing. Marc Sens (IAV GmbH)	› R 603 (pp. 05–38) › H 1298 (2022)
1393	› **Fretting Fatigue Strength Assessment:** Extension of the calculation concept for fretting fatigue on cast iron and aluminium materials › BMWK/AiF, FVV	› Prof. Dr. sc. Alexander Hasse (IKAT, TU Chemnitz) › Dr.-Ing. Reiner Böschen (Rolls-Royce Solutions GmbH)	› R 603 (pp. 342–364)
1394	› **Modelling of Pre-ignition in Gas Engines:** Phenomenological modelling of the pre-ignition in gas engines › BMWK/AiF/CORNET, FVV	› Prof. Dr.-Ing. Michael Bargende (IFS, Universität Stuttgart) Prof. Dr. Kai Herrmann (ITFE, FH Nordwestschweiz) › Dr.-Ing. Markus Wenig (Winterthur Gas & Diesel Ltd.)	› R 603 (pp. 314–341)
1396	› **Fuel Oil Flow Measurement:** Clarification of fuel and oil flow behaviour around the piston rings of internal combustion engines › BMWK/AiF/CORNET	› Prof. Dr.-Ing. Gerhard Matz (IAM-Hamburg e.V.) Prof. Dr. Akihiko Azetsu (Tokai University) Prof. Dr. Malte Jaensch (NMA, TU München) Prof. Yuji Mihara (Tokyo City University) › Dr. Motoichi Murakami (Toyota Motor Corporation) Dr.-Ing. Marcus Gohl (APL Automobil-Prüftechnik Landau GmbH)	› R 603 (pp. 138–171) › H 1318 (2022)
1404	› **Simulation Damage Characteristics – Validation Tests and Lifetime Calculations:** Component tests for validation of computational methods for the life prediction of aluminium cast components under combined thermomechanical and high-frequency loading › FVV	› Prof. Dr.-Ing. Peter Elsner (Fraunhofer-ICT) Prof. Dr.-Ing. Thomas Seifert (HS Offenburg) › Dipl.-Ing. Jan Becker (Dr. Ing. h.c. F. Porsche AG)	› R 603 (pp. 172–205) › H 1316 (2022)
1425	› **Bidirectional Aeromechanical Coupling II:** Analysis of the effect of nonlinear aeroelastic interactions on the forced vibrations of coupled turbine blades › DFG, FVV	› Prof. Dr.-Ing. Malte Krack (ILA, Universität Stuttgart) Prof. Dr.-Ing. Reinhard Mönig (DLR-AT) › Dr. Andreas Hartung (MTU Aero Engines AG)	› R 603 (pp. 801–821)
1436	› **W14 Concepts / FKM Guideline:** Validated description of high-temperature crack behaviour within the FKM-Guideline »Bruchmechanischer Festigkeitsnachweis« › BMWK/AiF	› Prof. Dr.-Ing. Stefan Weihe (MPA, Uniersität Stuttgart) Prof. Dr.-Ing. Matthias Oechsner (MPA-IfW, TU Darmstadt) › Dr.-Ing. Shilun Sheng (Siemens Energy AG)	› R 603 (pp. 661–703) › H 1314 (2022)
1452	› **FVV Fuels Studies:** Transformation of mobility to the GHG-neutral post-fossil age – Part IVb › FVV	› Dr. David Bothe (Frontier Economics Ltd.) Frank Dünnebeil (ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH) › Dr.-Ing. Ulrich Kramer (Ford-Werke GmbH)	› R 603 (pp. 529–542) › H 1313 (2022)

Science for a moving society

New research programme

FVV's innovation and transfer network is all about dynamism, future, responsibility and power. Pre-competitive fundamental research produces sustainable, environmentally friendly and climate-effective technology solutions.

Industrial Collective Research is pre-competitive, forward-looking and open to all topics. FVV's pre-competitive research enables companies to solve shared technology problems and issues, such as on efficiency, life cycles, materials and the circular economy, at a systemic and component level on a sound scientific basis.

Unlike other transfer and technology platforms, FVV is a ›collaborative undertaking‹: industry-oriented research can only succeed where it is developed and designed together. That is why the expert groups come together on the second day of our transfer and networking event to determine their shared need for research and design projects accordingly, guided by experienced members.

Planned and ongoing projects // Status: 01.11.2022

The pre-competitive project work of the FVV enables collaborative research to be performed on fundamental questions, thus allowing the ever stricter requirements regarding materials, fuel efficiency and environmental friendliness to be met. In doing so, the FVV research programme also contributes to enhancing the competitiveness of its member companies.

Members of the FVV innovation network can find a list of all planned and ongoing projects in the FVV research programme in THEMIS:
→ **see p. 33**

86
planned projects

117
ongoing projects

203
projects in Q4/2022

70 %
financed through external funds | **BMWK/AiF, DFG, CORNET, …**

30 %
financed through **own funds**

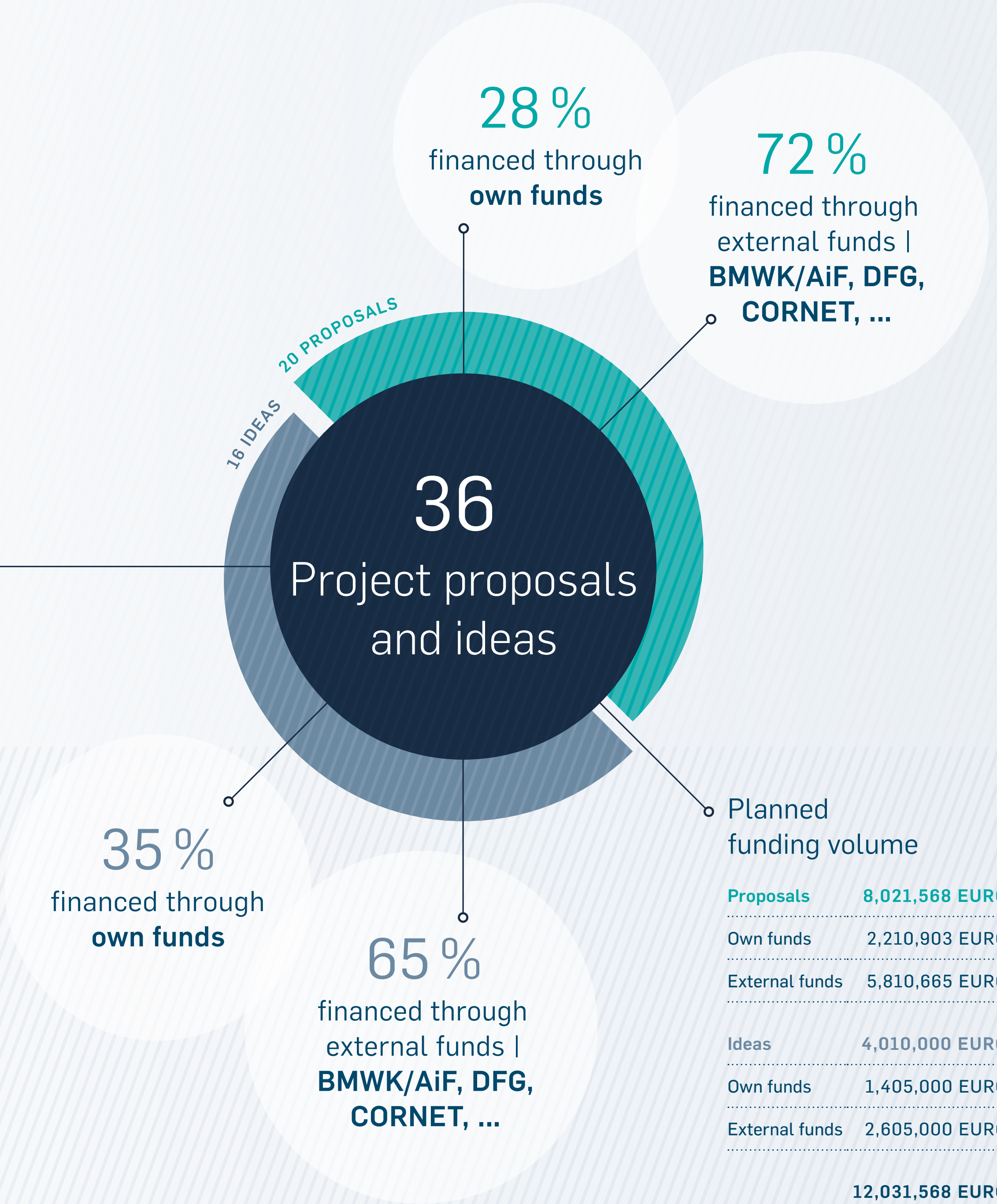
13
startet in Q3/2022 to Q1/2023

66 %
financed through external funds | **BMWK/AiF, DFG, CORNET, …**

34 %
financed through **own funds**

New project proposals and ideas // Status: 06.10.2022

In autumn 2022, a total of 16 new project ideas and 20 project proposals were up for discussion in the expert groups' face-to-face meetings in Würzburg and in the written silence procedure. The following package, with a planned funding volume of €12 million, was submitted to the FVV Board for final approval.

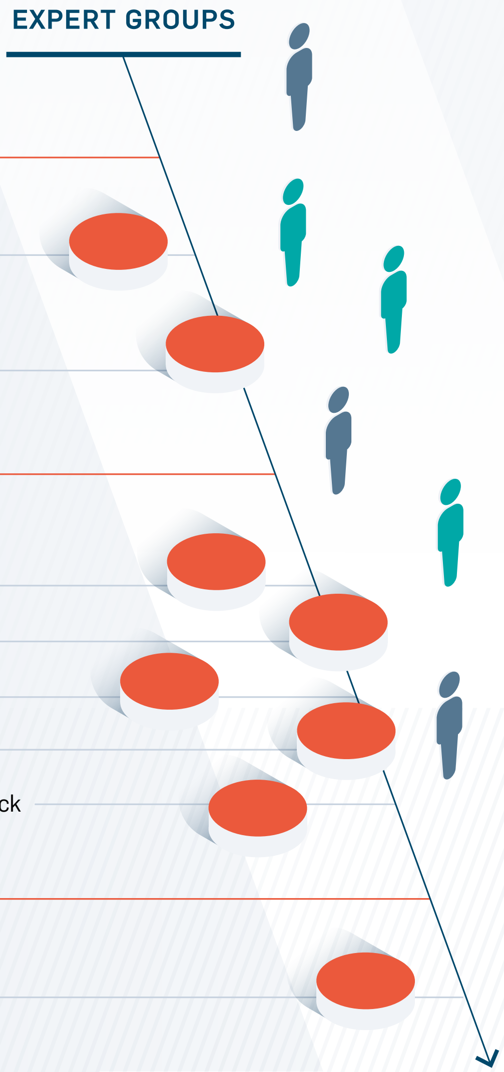


Planned funding volume

Proposals	**8,021,568 EURO**
Own funds	2,210,903 EURO
External funds	5,810,665 EURO
Ideas	**4,010,000 EURO**
Own funds	1,405,000 EURO
External funds	2,605,000 EURO
	12,031,568 EURO

Scientific coordination

Together we develop ideas for the future. Experts from member companies meet in the groups to identify common research needs and design projects accordingly. The Scientific Advisory Committee of the FVV appoints chairpersons for each group to lead the scientific work.



SYSTEM

Energy Infrastructure and Storage

NN

Sustainable Powertrain Systems

Thorsten Oberpenning, Rolls-Royce Solutions

SUBSYSTEMS

Energy Conversion Systems

- → **Engines** | Dr. Christian Weiskirch, MAN Truck & Bus
- → **Electric Motors** | Carsten Weber, Ford-Werke
- → **Fuel Cells** | Dr. Volker Formanski, BMW Group
- → **Turbo Machines** | Dr. Dirk Hilberg, Rolls-Royce Germany
- → **Zero-impact Emissions** | Dr. Volker Schmeißer, Daimler Truck

COMPONENTS

Materials Science and Recycling

Dr. Dieter Eppinger, SEG Automotive Germany

See also:
»Make it new – Science for a moving society« (ToR)
→ www.fvv-net.de/en/

Terms of references (ToR)

The assignment of research topics to the expert groups, which replace the former planning groups, is made along the system cascade of the V-model.

SYSTEM

Energy Infrastructure and Storage

Interaction of energy sources and system components, energy infrastructure and external storage

→ Chemical energy carriers and alternative fuels beyond application
→ Standardisation → Life cycle analyses

+ General issues related to demand and availability of energy sources / carriers
+ Production, quality, distribution and availability of hydrogen, electricity-based and alternative fuels
+ Standardisation topics on future energy carriers and related issues such as infrastructure and storage
+ Life cycle assessment (LCA)
+ Development of collaboration projects with other institutions to serve the interests of FVV members (e.g. workshop with the fuel / energy industry, …)

Sustainable Powertrain Systems

Road / rail vehicles: classic powertrains (ICEV), hybrid / electrified powertrains (PHEV, BEV, FCEV), aircraft engines, marine propulsion, mobile machinery, power systems

→ Energy storage within the application
→ System efficiency → Air pollution, global warming, noise, sound, radiation
→ E-machine combined with battery

+ Questions on energy storage in the aforementioned applications
+ System efficiency of energy conversion processes e.g. charging, system control / regulation, sensor technologies, …
+ Thermal management
+ Zero-impact emissions, greenhouse gas emissions (e.g. CO_2), noise, sound, electromagnetic compatibility (EMC)
+ E-machine combined with battery / ICE [interface to E-MOTIVE platform]
+ Impact of legal, social and political requirements onto powertrain systems, circularity
+ Development / engineering of tools for i.e. the system architecture and interaction of powertrain assemblies

Energy Conversion Systems

Innovative and / or optimised energy conversion systems minimising environmental impact and maximising process efficiency and engine performance

SUBSYSTEMS

→ Engines

+ All conventional engine development topics
+ Optimisation and development of new energy conversion processes focusing on e.g. increasing process efficiency of future varieties of fuels (including use of hydrogen)
+ Reducing the environmental impact
+ Process-focused adaptation of related components and (sub-) assemblies
+ Effects of increasing electrification to the ›engine‹ subsystem and its aggregates
+ Digitalisation
+ Development and improvement of related development / engineering tools based on changing and adopting application / subsystem requirements

→ Electric Motors [interface to E-MOTIVE platform]

+ Improvement of electrical motor properties in mobile applications
+ Electrical energy storage systems (battery)
+ Power electronics of the electrical motor and electrical energy storage system
+ Application-focused adaptation of related components and (sub-) assemblies
+ Development and improvement of related development tools e.g. simulation tools, measurement and testing methods

Energy Conversion Systems

Innovative and / or optimised energy conversion systems minimising environmental impact and maximising process efficiency and engine performance

SUBSYSTEMS

→ Fuel Cells [interface to E-MOTIVE platform]

+ Air and hydrogen system path, media conditioning and purification
+ Thermal management of the fuel cell stack
+ Optimisation of fuel cell specific components and (sub-) assemblies e.g. ion exchanger, compressors, …
+ Research on materials at fuel cell specific conditions and effects, e.g. on bipolar plates, membranes, sealings concerning stack performance, loading characteristics, ageing (durability, degradation), humidification, …
+ Stack performance / efficiency improvements e.g. performance effects of component and assembly tolerances
+ Safety requirements and definitions
+ Development of defined evaluation methods towards industry standards (generic, ›best practice‹)
+ Technology comparison PEM, High-temperature PEM, SOFC
+ Development and improvement of fuel cell specific development tools e.g. simulation tools, measurement methods (e.g. impedance analysis)

→ Turbo Machines

+ All conventional turbomachinery development topics
+ Optimisation of aerodynamics
+ Optimisation of turbomachinery specific components and (sub-) assemblies
+ Research on materials of turbomachinery specific conditions and effects; e.g. high-temperature, loading characteristics, ageing, resonances, use of hydrogen
+ Development and improvement of turbomachinery specific development tools

Energy Conversion Systems

Innovative and / or optimised energy conversion systems minimising environmental impact and maximising process efficiency and engine performance

SUBSYSTEMS

→ **Zero-impact Emissions**

- + Exhaust aftertreatment concepts, systems and components
- + Alternative aftertreatment system technologies and approaches
- + Effects of the use of alternative fuels and operating liquids
- + Interactions of exhaust components, primary and secondary exhaust species
- + Non-exhaust emission evaluation of all mobile applications (incl. electrified), e. g. brake dust, tyre abrasion, …
- + Interaction emission and immission / air quality
- + Carbon capture approaches and technologies
- + Development and improvement of related development tools, e. g. simulation tools, measurement and evaluation methods

Materials Science and Recycling

All conventional topics on materials research in connection with new energy sources, production methods and recycled materials

COMPONENTS

→ Strength → Tribology → Recycling

- + Tribology, strength, fatigue models and improvements
- + Properties, strength and fatigue characteristics of materials for electric powertrains (e. g. copper)
- + Durability and robustness of electrically isolating materials (e. g. aspect of partial discharge, …)
- + Impacts and interactions on components and (sub-) assemblies caused by novel energy types (e. g. hydrogen, e-fuels, methanol, …)
- + Components made by additive manufacturing, their properties and related method approaches
- + Material properties impact of recycled materials
- + Energy footprint of components and assemblies depending on material and manufacturing process, circularity
- + Development and improvement of group related development tools e. g. simulation tools, measurement and evaluation methods

THEMIS Database

Members of the FVV innovation network can find a list of all planned and ongoing projects in the FVV research programme and dates for the discussion groups, workshops and project user committees in THEMIS.

Project list

Status: 01.11.2022

Research programme

Status: always up-to-date

Meeting dates

Status: always up-to-date

The publication ›**The FVV Transfer + Networking Event | Autumn 2022**‹ is available online:

→ www.fvv-net.de/en/ | Transfer | Downloads | Publications

Science for a
moving society

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Transfer // Industrial Collective Research (IGF) empowers companies to solve joint research and technology problems on a science-based approach. It provides access to a continuous stream of new knowledge they can use to create their own products, processes and services. Industrial research and development benefits from the fact-/field-based collaboration with the science community, universities and non-profit research institutions, on the future of technology. This creates innovative power in industry and excellence in research, teaching and learning.

Networking // The research implemented by the FVV is based on a long-term cooperation between the partners. In spring and autumn, around 300 experts meet regularly at the FVV Transfer + Networking Events. This report from the science series FVV Prime**Movers.** Technologies. summarises the main results.

FVV e V

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