Questionnaire to automotive suppliers
Answers from BOSCH

Bosch is one of the world's biggest suppliers of injection technology and one of the suppliers of engine control units for the diesel engines being investigated since September 2015 by authorities in the U.S., Germany, and other countries.

Because of its role as a supplier, Bosch launched its own internal investigation. Bosch is also in constant dialogue with the relevant authorities. Due to the legal situation following the ongoing investigations of U.S., German and other authorities regarding the VW diesel engines, Bosch cannot comment on questions regarding issues of these investigations.

Some of the questions relate to strategies or motivation of manufacturers (OEM) and should be addressed to the OEM directly.

The subjects addressed by the questions from EMIS are complex and can only be explained within this document in a simplified manner. We may only be able to address some of the aspects mentioned and would like to point out in advance that simplified description will by nature involve a certain degree of vagueness in that the background cannot reliably be described in all details. Therefore, please bear this proviso in mind when reading the following statements.

Question 1

1 The Electronic Diesel Control manages the engines of diesel vehicles, which several companies produce. Who does the programming of the EDC? How are decisions made to optimise the engine?

The software in an EDC is compiled from different sources. In the software, there are Bosch functions (cross customer functions) that are used at most (but not with all) of the OEMs. However, a large part of the software is specified by the OEM. Specifications can also change or replace functions of the Bosch platform. Each OEM defines its own scope of functions consisting of

- its own functions (developed by the OEM itself or by third parties)
- functions developed by the supplier (e.g. Bosch) on behalf of the OEM (customer platform)
- functions adapted from the supplier platform
- supplier platform functions.

The proportions of these four function types are frequently altered – from complete provision of the application functions by the OEM up to a complete equipping of the EDC with function types 2-4.

Over the years and in the course of individual projects, this OEM-specific scope of functions forms the basis for the scope of further software development defined within the framework of the OEM commissions.

The details of the functions may be very different. In order to protect expertise and differentiate themselves from competitors, many OEMs develop some own software functions, which Bosch are then given as the object code (machine code) for integration into the overall software. The functionality contained in the code is not disclosed to Bosch.

The OEM has complete knowledge of the entire vehicle and all of its components. The final calibration (application, calibration) of the program labels and codes is predominantly the responsibility of the OEM or performed in accordance with the OEM's detailed instructions. The reason for this is that proper performance of the calibration requires knowledge of the vehicle's entire engine and emissions technology and other performance data, which often only the OEM has and generally not the supplier. Without this knowledge, it is generally impossible to clearly identify the effects of the labels and functions and their calibration on the vehicle’s behavior.

For the same reason the responsibility for the engine optimisations also lies with the OEM.

Question 2

2 How would you describe the economic power balance between car manufacturers and car suppliers: is the supplier solely an executive company for components which are predefined by the car manufacturer in great detail, or does the supplier offer their own products, which are merely bought by the car manufacturer? Can the supplier sell their products to all OEMs or are the products mostly too tailor-made/bespoke to sell to others?

Cooperation generally takes place in the form of joint project development. The OEM coordinates the requirements of the vehicle manufacturer and their prioritisation, Bosch estimates the implementation effort and carries it out accordingly. During this process, the OEM has complete knowledge of the entire vehicle and all of its components. Bosch has the status of a subsystem and component supplier. The products are OEM-specific and can only be used following corresponding adaptation to the vehicle and therewith to the drive-specific situation. As depicted in question 1, the ECU ultimately used by the OEM nearly always consists of functions that are mainly specified by the OEM; sometimes in every detail, which form a customer specific platform together with Bosch components and are frequently supplemented by the OEM through their own functions that often cannot be read by Bosch (in the form of a “black box”).

Question 3

3 Modern cars and their components are largely controlled by software. For the moment, the software is not part of the type approval, in-serve-checks, in-production-conformity-checks or general inspections. Do you see any reason – be it technical or other – why software should remain excluded from those tests? Concerning engine control software: how difficult is it to re-engineer or manipulate such software? In what ways can “cheat-codes” be integrated and hidden/disguised in such software?

3.1 Modern cars and their components are largely controlled by software. For the moment, software is not part of type approval, in-service-checks, in-production-conformity-checks or general inspections. Do you see any reason - be it technical or other - why software should remain excluded from those tests?

Software is indeed key to the functioning of many complex automotive components and systems. This is also true of systems that are safety-relevant (e.g. electronic stability control) or emissions-relevant (e.g. exhaust gas treatment systems). We believe that additional clarification of the existing rules could prove worthwhile, especially in the area of exhaust emissions. When setting regulatory requirements in this area, the purpose of such requirements should be kept in mind, i.e. preventing that software inappropriately reduces emissions reduction performance. Given the complexity of modern engine control units (ECUs), disclosure of the entire software would probably not serve this purpose. Disclosing the thousands of program functions, tens of thousands of variables and hundreds of thousands up to millions of lines of source code of each individual ECU would present the type-approval authorities with enormous challenges in terms of both effort and capacity, which is why the effectiveness and meaningfulness of such a measure seems questionable. Moreover, disclosing the entire software would potentially make proprietary know-how of ECU manufacturers available to competitors. Therefore, Bosch welcomes the new requirement based on U.S. practice that was introduced with Regulation 2016/646, whereby information on the Base Emission Strategy (BES) and descriptions of all Auxiliary Emission Strategies (AES) need to be appended to the application for the granting of EG type approval.

3.2 Concerning engine control software: how difficult is it to re-engineer or manipulate such software? In what ways can "cheat-codes" be integrated and hidden / disguised in such software?

ECU software developers distinguish between programming and calibrating the code. Functionality is ensured by combining the code and calibration data. The code of an ECU is comprised of software code of the supplier and customer specific code (i.e. code developed on behalf of the OEM and code provided by the OEM that has been implemented by the OEM itself, by other first tier suppliers or by software service providers). Bosch develops code ordered by the OEM in compliance with the requirements of the OEM. Code provided by the OEM is merely integrated by Bosch into the entire program. Calibration is largely performed by, or on behalf of, the OEM.

It is possible to protect the software (code and data) of state-of-the-art generations of ECUs from third-party manipulation using state-of-the-art automotive technology. Nevertheless, it must be made clear that no software is 100% secure. Despite extensive efforts, it is not possible to rule out completely that software manipulations will occur. However, Bosch's platform solution offers security functionalities with which any unauthorized manipulation of programs or data (e.g., fitting of cheat code) can be prevented or detected according to the most recent automotive industry’s state-of-the-art. Among other things, appropriate mechanisms prevent that content is read or written over; access keys (so-called software signatures) prevent the installation and activation of manipulated software and diagnostics access is deactivated or adequately protected.

The above security features are recommended by Bosch. However, ultimately, it is the OEMs who decide what safeguards are active in the control unit.

Question 4

4 When the software is adapted to protect the engine, how is the testing performed to verify that it works properly? Have you ever suspected any possibility of software adaptations to the testing cycle?

4.1 When the software is adapted to protect the engine, how is the testing performed to verify that it works properly?

In general, all physical functions of the engine are controlled by the effect of the "software" – meaning the logical link – in conjunction with the "calibration".

A simplified example: The engine's idle speed can be set based in part on the coolant temperature. When the coolant temperature rises, the engine's idle speed is lowered via a functional link. This ensures that the engine can reach its operating temperature as quickly as possible (and therefore runs in its typical working range), but runs optimally in terms of "ignition failures" when it is cold. In this process, the thresholds for temperatures or the temperature range in which the idle speed is changed are determined only by entering the temperature values, i.e. by way of calibration with application (so-called calibration). The changes to idle speed and idle speed regulator are achieved by these logical links, also called functionalities.

This example shows that, in many cases, the software (in terms of the logical link) by itself has no functions yet. In these cases, it is only when the "application data" (= adaptation data with which the logic provided by the software is adapted to the specific engine or vehicle) has been entered that the software is given a function.

As stated under Question 1, the final calibration (application, calibration) of the program labels and codes is predominantly the responsibility of the OEM and/or performed in accordance with the OEM's detailed instructions. The reason for this is that only the OEM has the complete knowledge of the entire vehicle system and all of its components. This is especially true where emission-reducing devices are controlled in order to protect the engine. The OEM validates the behaviour according to the necessity of the observed functionality. For example, winter, summer, high altitude, test bench and long-term tests take place. The scope and type of testing and safeguarding at the vehicle level is established by the OEM.

Question 5

5 Can you provide us with some information on the encryption of the software and on the on-board diagnostics data streams: who is developing the code system and who has final access? How should this encoding be modified in order to enable compliance testing by independent authorities?

5.1 Can you provide us with some information on the encryption of the software and on the on-board diagnostics data streams: who is developing the code system and who has final access?

The software (code and data) of current generations of ECUs can be protected from manipulation using state-of-the-art automotive technology. Bosch's platform solution offers different functionalities with which any unauthorized manipulations of programs can be prevented or detected (see answer to question 3.2). Among other things, through "Flash Read/Write-Protections" as well as access-protection functions it is prevented that content is read or written over. Software signatures ("keys") prevent the installation and activation of manipulated software, and diagnostics access is deactivated or adequately protected in series-products.

The above security features are recommended by Bosch. However, ultimately, it is the OEMs who decide what safeguards are active in the control unit.

Regarding the communication between a tester and control unit, it is necessary to differentiate between two cases:

- Reading: Different data on the standards is provided via the diagnostic interface, e.g. OBDII. This information is openly available in order to ensure that the vehicles can also be maintained by independent repair shops.
- Writing: Writing (e.g. flashing code or data) is only possible following successful authorisation. Control over the process used is with the OEM.

5.2 How should this encoding be modified in order to enable compliance testing by independent authorities?

Bosch believes that successful compliance testing by independent authorities can already be achieved with the current software. Two parallel measures will ensure compliance: in-service conformity testing and disclosing information of the emission control strategy.

Following the RDE type approval requirements, Conformity of Production (CoP) testing screens vehicles not older than 5 years or exceeding 100.000 kilometer mileage for conformity on the road. As already explained above under 3.1, Bosch welcomes the fact that – similar to practices in the U.S.– information on the Base Emission Strategy (BES) and descriptions of all Auxiliary Emission Strategies (AES) now will need to be disclosed by the OEM in the type approval process within the EU as well and will therefore be subject to monitoring by the responsible licensing authorities.

These two measures will ensure that manufacturers comply with emission limits without relying on illegal emission control measurements. At the same time, it spares authorities from the almost impossible task of analysing the entire complex modern engine control units, with thousands of programs, tens of thousands of variables and hundreds of thousands to millions of lines of source code of each individual ECU.

Question 6

6 Would you confirm that it is a regular procedure that OEMs are adopting the electronic control unit (ECU) software to their specific needs? Or is the supplier (of the car computer’s software) actually the only party who can do such calibration? If you confirm the first option, is it possible for car manufacturers to change the settings of ECU to decide when the different systems, such as EGR or exhaust gas treatment, should be switched off? Who has in the end the formal responsibility in this regard for the final (emission) performance of the vehicle? What are usually the contractual agreements between suppliers and OEMs in this regard?

6.1 Would you confirm that it is a regular procedure that OEMs are adopting the electronic control unit (ECU) software to their specific needs? Or is the supplier (of the car computer’s software) actually the only party who can do such calibration?

As far as Bosch is able to assess this question, the ECU is adapted to the customers' special requirements via functionality and calibration. This is done by the OEM, or by the OEM commissioning Bosch (or, if applicable, a service provider) the latter only or directly by Bosch if, according to the contract, the responsibility lies with Bosch.

6.2 If you confirm the first option, is it possible for car manufacturers to change the settings of ECU to decide when the different systems, such as EGR or exhaust gas treatment, should be switched off?

Roughly speaking, in the development of control unit software, one must differentiate between the programming of the code on the one hand and its calibration (application, calibration), i.e. assigning values to individual labels, on the other hand.

As already shown, each OEM defines its own functional scope over time (see question 1).

The function is depicted by the interplay of functional logic (software) and its adaptation by entering data (calibration, application). Another range of effects can be set by the calibration.

A function provided in the software can also be "calibrated neutrally" so that this function no longer develops any effect.

As discussed under question 1 and question 4, ultimate responsibility for incorporating the software into the vehicle's emission control system of the vehicle and for the effects of the software on the NOx emission behaviour is generally borne by the OEM in the OEM-supplier relationship. However, there are also projects for which the supplier also carries the entire calibration and is contractually responsible for it. Nevertheless, the OEM is solely responsible here as well for complying with the requirements in the type approval process, in particular with respect to disclosing the emission strategies.

6.3 Who has in the end the formal responsibility in this regard for the final (emission) performance of the vehicle? What are usually the contractual agreements between suppliers and OEMs in this regard?

In his answer to question 8 at the meeting of 16 June 2016, Prof. *Borgeest* provided an essentially correct rough summary as to how ECU software in today's diesel passenger cars is normally structured and how tasks are typically allocated between the supplier of the control unit and the OEM.

Roughly speaking, in the development of control unit software, one must differentiate between the programming of the code on the one hand and its calibration (application, calibration), i.e. assigning values to individual labels, on the other hand.

Based on our experience, today ECU software for modern diesel passenger cars consists of approximately 35.000 labels, sometimes up to 90.000 labels (this is higher than the figure of 20.000 given by Prof. *Borgeest* in his answer to question 1 at the meeting of 16 June 2016).

Additionally, as Prof. *Borgeest* already described, in the development of the program (of files and codes), one must also differentiate between the standard software (the platform with standard functions), which is developed by the individual supplier and represents the core of the supplier's software, and the customer specific requirements which are customized to the individual OEM and specific vehicle. The customer specific requirements complement or modify the platform. The proportion of customer specific requirements relative to the specific platform functions varies greatly depending on the customer and the market. These customer specific functions and labels are developed based on the OEM's instructions.

Furthermore, most OEMs themselves add functions and constructs they have developed to parts of the software, the exact content of which the supplier itself cannot see in most cases (like a "black box") and which it merely integrates in the status of the entire program. For such parts of the software, the supplier typically has no access rights and does not receive any software documentation. Some OEMs have their own large development departments whereas others transfer large parts of their software development to suppliers, in particular to further software providers.

The final calibration (application, calibration) of the program labels and codes is usually the responsibility of the OEM or performed in accordance with the OEMs detailed instructions (see answers to questions 1 and 4). Bosch especially designs "hardware proximate" functions to ensure that, for example, fuel injectors are capable of injecting without causing the motor to break down and without damaging the injectors, but, in the end, the customer's calibration determines when and how the hardware is actually activated.

As between the OEM and the supplier, it is as a general rule that the OEM is ultimately responsible for integrating the software into the vehicle's emission control system and for the effects of the software on the NOx emission behaviour. There are, however, projects where the supplier also performs the entire calibration and is responsible for such calibration under the relevant contract. However, also in these cases responsibility for complying with the requirements of the type-approval procedure remains solely with the OEM. Bound by duties of confidentiality to the OEMs, Bosch cannot make any statements about the contractual agreements it has made with its customers without their consent.

Question 7

7 Do you produce (or do OEMs request) emission control systems or components of such systems of different operational limits (e.g. ambient temperature of engine loads) or quality (design, components or materials used) or of different durability for OEMs in U.S. and EU markets? And within the EU market? Can the emission control systems, individually or different technologies combined, work under all ambient conditions reasonably encountered in Europe with best available technologies today?

7.1 Do you produce (or do OEMs request) emission control systems or components of such systems of different operational limits (e.g. ambient temperature of engine loads) or quality (design, components or materials used) or of different durability for OEMs in U.S. and EU markets? And within the EU market?

Firstly, it should be noted that Bosch does not deliver any (complete) emission control system, but only partial systems that contribute towards the overall emission result. In the course of the development process, Bosch seeks to determine the market requirements (i.e. the requirements of the engine manufacturers) for the respective product, whereby the climate-related boundary conditions of the regions do not play a significant role. This can be explained by taking the injection system as an example. The basic design – i.e. the fundamental geometries of the products, the materials used and the production and heat treatment processes employed – does not vary for the different regions where it is used. Nevertheless, there are differences in the hardware design of the injection system, and these differences depend on how the product is used and thus on the requirements of the customers or engine manufacturers.

On the one hand, this affects the geometric conditions in the engine. For instance, the injector has to be adapted so that it fits into the cylinder head of the engine. Moreover, the injection nozzle (lower part of the injector) needs to be adapted with respect to the number of injection holes and the direction of the injection jets (jet position) to provide an optimum combustion process in the engine (each engine has different geometric dimensions – especially in the combustion chamber).

In addition, there are also hardware adaptations that are required for the different fuel properties found around the world and used to increase robustness. One well-known measure involves coating certain components (e.g. C-coating) of the injection system to counteract increased wear on the component due to the possible use of "poorer" fuels.

However, we cannot answer whether the same emissions behaviour is achieved on both markets in the vehicles of the customers, since this depends on the calibration of the wide range of functionalities and of the behaviour of the engine with respect to the emissions emitted by the engine.

7.2 Can the emission control systems, individually or different technologies combined, work under all ambient conditions reasonably encountered in Europe with best available technologies today?

An emission control system always consists of a great number of components and subsystems that contribute towards the emission result. In this respect, various technologies known to us are combined in every one of the applications, e.g. exhaust gas recirculation, charging and different catalytic converters and filters. In addition, there are also actuators and sensors for control functions, including a program structure that describes a linking logic. The latter – as already explained elsewhere – contains the actual effect through the calibration.

These systems are functional under all frequently encountered environmental conditions that can be realistically expected, provided that physically necessary and unavoidable correlations are taken into account. An example of these unavoidable correlations:

If the vehicle was parked for a prolonged period, then all components, including the engine and catalysts will have assumed the temperature of the surroundings. After starting, it then necessarily takes a certain amount of time before the catalytic converters, for example, are heated up to a temperature level that makes the pollutant-reducing effect possible. It is also inevitable that heating up takes longer at an ambient temperature when parked at -5 °C than at, for example, 20 °C.

It is also well known for example that a storage catalyst (NSC) can reduce NOx at lower exhaust gas and component temperatures more easily than an SCR catalyst can. Nevertheless, the above statement applies for storage catalysts and SCR systems.

In our opinion, evaluating something as the "best available technology" may not be expedient, since it is often not clear in many cases. The focus is currently on NOx, possibly due to actuality reasons. It must be taken into consideration that NOx with unburned carbon hydride (HC), carbon monoxide (CO) and particles (PN, PM) is in a "trade-off relationship" as a rule, i.e. the improvement of NOx, for example, generally results in the deterioration of other components. For this reason, a balanced observation of all limited exhaust gas components may well be necessary in our opinion. Based on our experience, this observation often reveals various "best available technologies" for different vehicles or a number of advantages and disadvantages for the different solution approaches, making it impossible to make a clear decision with regard to "the best" approach. In addition, the exhaust after-treatment systems that correspond to the BAT standard also require a sufficient level of technical development for the other engine and vehicle components.

Question 8

8 Is it possible to meet the passenger car NOx emission limit values required under California law (CARB, app 35g/km) in normal use, i.e. real-world driving, without SCR technology? What about the EU 80 mg/km NOx limit? What is the approximate consumption of AdBlue for an average passenger car over 10.000 km under optimal emission control performance in normal use? What should be the AdBlue tank size to ensure adequate quantity of the urea reagent used through the cars' lifetime (replenish every 10.000 km)? Does your technology have operational boundaries linked to ambient air temperature or engine out temperature? What, if any, engine conditions impact SCR effectiveness?

Answering this question depends on the observance of the complete system of each vehicle. It is for this reason that it should be answered by the OEM. The supplier is generally unfamiliar with this complete system and is neither responsible for complying with the type approval requirements nor for maintaining the emission limit values in the individual vehicles.

However, it needs to be clarified that the legal situation according to California law is very complex and that the emission limit value of around 35 mg/km for NOx referred to in the question is not comparable to the EU limit value of 80 mg/km.

Accordingly, Bosch is recommending, and for many years has already been recommending, the use of an SCR system or a combined system consisting of a storage catalyst and SCR system for all limit value levels in the U.S.

8.1 What about the EU 80 mg/km NOx limit?

Maintaining the limit value of 80 mg/km in the NEDC cycle can also be achieved with various technologies during "Real world driving"; an SCR system with AdBlue dosing is not always necessary. "Real world driving", as described in RDE package I and II, can be fulfilled at the first level (cf = 2.1) with certain vehicles (= due to the engine-transmission-vehicle combination, program map areas favourable to emissions are mainly addressed in driving operation), an optimised engine and an excellently designed storage catalyst system, possibly without an SCR with AdBlue dosing. However, we see limited robustness of the storage catalytic system when there is no active SCR system, especially when driving uphill at high speed, therefore we generally recommend the use of an active SCR system.

8.2 What is the approximate consumption of AdBlue for an average passenger car over 10.000 km under optimal emission control performance in normal use? What should be the AdBlue tank size to ensure adequate quantity of the urea reagent used through the cars' lifetime (replenish every 10.000 km)?

In our opinion it is not possible to answer this question in a way that is universally applicable. The required dosing quantity is essentially proportional to the NOx mass that is to be reduced via the SCR catalytic converter. The distribution of the NOx reduction task between the engine and after-treatment of exhaust gases, the design of the catalytic converter system and the driving profile will significantly influence the AdBlue consumption. That is why it is not directly possible to draw conclusions concerning the range of an AdBlue tank filling from the size of an AdBlue Tank.

8.3 Does your technology have operational boundaries linked to ambient air temperature or engine out temperature?

The function of each catalytic converter system mainly depends on the temperature of the exhaust gas. In our experience, this has a dominant influence. The outside temperature tends to have a rather indirect effect (increase of the heat transfer from the exhaust gas flow outwards and – especially – an extension of the warm-up time after a cold start). The component design was already described above.

8.4 What, if any, engine conditions impact SCR effectiveness?

SCR catalytic converters are often sensitive to the NO/NO2 ratio, to increased HC emissions and to temperatures that are generally too low.

NO/NO2 can hardly be influenced in the engine; for this reason, the coating properties of the DOC, DPF and SCR catalytic converter must be suitably coordinated.

Increased HC emissions must be avoided in the engine application and in the application (calibration), for example in the DPF regeneration. There is generally a trade-off between "engine out" HC and NOx, i.e. there is opposite behaviour.

Temperatures that are too low can be influenced to a limited degree with temperature management measures and through the design of the engine and after-treatment system (located close to the engine, optimised surfaces, insulation, etc.).

Question 9

9 In your opinion, how would you see the possibility of supplying specific fleet, e.g. delivery vehicles, for low emission zones planned in some European cities?

Existing environmental zones in the EU have hitherto specified entry restrictions to a maximum of EURO 4; in this respect there are already enough products on the market that consumers and the public sector can access. Stricter measures for environmental zones are currently being discussed in a number of Member States (UK, Germany, et al.). As far as we know, entry restrictions of at most EURO 5 are being planned. Our findings show that it is possible, using modern after-treatment of exhaust gases processes, to comply with the limit values that are valid for real driving behaviour, starting from 2017. Currently, a few EURO 6 vehicles already comply with these limit values. Induced by the fleet renewal, more and more vehicles with low emission values will therefore come onto the market.

The introduction of the "in service conformity" for heavy commercial vehicles has led to significant reductions in emissions behaviour in real traffic. In many cities this has been adopted accordingly, for instance by choosing the modern EURO 6 diesel buses for new acquisitions for bus transport, as these distinguish themselves through their lower consumption and emissions behaviour.

The resolved RDE requirements apply for light commercial vehicles; we are supplying the corresponding technology for meeting these requirements and we hope to see significant improvements in real driving behaviour.

Separate development concepts related to specific environmental zones are not planned, since a possible consequence of market segmentation could be the minimisation of scaling effects. With respect to economic and industrial policy, environmental zones oriented towards the existing EURO standards make sense, since the industry can adjust its production technology accordingly.

It is natural for a supplier to make general contributions so that combustion engines and electric motors work with increased efficiently and functionality as well as with lower levels of noise and emissions.

In general, the elaboration of logistics concepts is incumbent on the public sector, carriers and logistics companies. Many cities are already dealing with sustainable supply chains; we support this process, such as by optimising vehicles in both the passenger car as well as in the commercial vehicle area by hybridisation and by producing components for delivery and electric bicycles and providing networking technology.

Moreover, we are always ready to talk with city representatives, logistics companies and carriers in order to work together on technical solutions that will improve mobility in urban spaces on a sustainable basis.

Question 10

10 In a previous EMIS hearing, suppliers of emissions control technologies and catalysts argued that modern catalyst technology (emissions after-treatment after EGR) is fully functional independently of ambient temperatures. It was also clarified that with intelligent thermo-management, modern engines, including their EGR, work perfectly well at temperatures ranging from below zero up to 40 degrees centigrade. Nevertheless, OEMs still argue in favour of the so called “thermo windows” to protect the engine and parts of the emissions control system. Could you explain this contradiction?

10.1 In a previous EMIS hearing, suppliers of emissions control technologies and catalysts argued that modern catalyst technology (emissions after-treatment after EGR) is fully functional independently of ambient temperatures.

As already explained above in detail, catalytic converter systems are essentially dependent on the temperature of the exhaust gas. There is a clear connection to the ambient temperature for the warming-up phase of a cooled-off system. In this respect, we do not agree with the statement *"fully functional independently of ambient temperatures"*; at very least, "fully functional" cannot be understood as an "identically efficient function as with a warm system in a warm environment”.

In stabilised operation (i.e. when warming up is completed), the ambient air temperature is then only of minor significance.

10.2 It was also clarified that with intelligent thermo-management, modern engines, including their EGR, work perfectly well at temperatures ranging from below zero up to 40 degrees centigrade*.*

We share the opinion that – assuming suitable systems and components are present– the engine function, including exhaust gas recirculation, is possible in the temperature range indicated. However, one detail of the statement needs to be emphasized: If "perfectly well" is understood as being "with exactly the same NOx reduction effect as with a warm engine in a warm environment", then this is not true.

As it has already been mentioned above, there is basically trade-off behaviour between NOx reduction and HC emission. For vehicle operation in a colder environment, this means that there tends to be a reduction in NOx emission and an increase in HC. When exhaust gas recirculation is activated, it is now thoroughly probable that the increased HC mission will lead to an HC condensation precipitation in the EGR system and that, for instance, components will stick and/or deposits will form that may adversely affect the transfer of heat into the EGR coolers. This in turn can result in a decline of the NOx reduction effect or to a system failure.

From our perspective, this problem can be mastered by switching off EGR cooling or by switching from (strongly cooled) low-pressure EGR to (non-cooled) high-pressure EGR.

We assume that malfunctions of the EGR system can be avoided in many cases by using such measures; however, the NOx reduction effect of the EGR also decreases through these measures. Nevertheless, it is our experience that NOx emissions from the engine will also be considerably lower with the reduced EGR effect than without EGR.

10.3 Nevertheless, OEMs still argue in favour of the so called "thermo windows" to protect the engine and parts of the emissions control system. Could you explain this contradiction?

Since Bosch does not manufacture any EGR systems, we are unable to make any valid statement in this regard due to the lack of component development.

Question 11

11 At a meeting of transport ministers in Brussels on Tuesday, 7 June, the following wording on whether the ban of defeat devices should not apply was proposed: "even if the best available technologies are included, no other technology is available to protect the engine against damage or accident and for safe operation of the vehicle". In this regard, what is your understanding of "the best available technologies"? Can you provide us with a list of currently "best available technologies" for lowering NOx and CO2 emissions?

Due to the complexity of the technical relationships and mutual dependencies, we feel that it is impossible to achieve the desired result solely with the presence of certain components, systems or functions. (One example of functions was given with the engine's idle speed in the responses for the first part.) In order to achieve the intended goal, i.e. emissions that are as low as possible in as many relevant driving conditions as possible, it is our conviction that taking the approach with the RDE regulation is expedient. Of course it is necessary, that in the still-pending 4^{th} package, an effective "in-service monitoring" is regulated.

As already stated above, we do not regard the "best available technology" as being a suitable approach for a regulation, since we do not believe that there are any technical measures that do not combine advantages and disadvantages.

Therefore, it is not possible to indicate a list of best available technologies. The situation is similar for CO_2.

Question 12

12 How many devices designed to switch off emission control systems at given circumstances are available on the market and how do they work in practice? Could you give us an estimate of the per vehicle cost to mount such devices?

Bosch does not produce any devices that serve the purpose of reducing or switching off the functionality of the after-treatment of exhaust gases. We are therefore unable to provide information about such devices.