Developing the future.

InCar®

THE INNOVATIVE SOLUTION KIT FOR THE AUTOMOTIVE INDUSTRY

ThyssenKrupp
Ladies and Gentlemen,

On the following pages we would like to introduce you to InCar® – the most extensive research and development project undertaken in the ThyssenKrupp Group for innovations in automotive design.

InCar® is customer oriented: The development priorities were defined in cooperation with our automotive partners. The focus is sustainable improvements in weight, cost, function or emissions. Development work resulted in more than 30 innovations for body, chassis and powertrain: a solution kit from which you can choose what matches your own development needs.

InCar® sets standards with the maturity and proven feasibility of its newly developed solutions. InCar® innovations can be adapted quickly and easily to individual customer requirements. A manufacturer-neutral benchmarking process makes the advantages of each InCar® solution transparent and comparable with the current state of the art. The results of a comprehensive CO₂ assessment are also included.

InCar® draws on the entire automotive expertise of the ThyssenKrupp Group. Numerous companies with material development, engineering, part production, and equipment, prototype and tooling manufacture know-how worked together closely in the InCar® team. Each of these companies is a leader in its own specialist area. And together they represent the ThyssenKrupp Group’s tradition as a partner to the automotive industry dating back more than 100 years.

The goal of the InCar® projects is your success – based on validated, easy-to-implement innovations. Find out more in this brochure.

Sincerely yours,

Dr. Ulrich Jaroni
Member of the Executive Board of ThyssenKrupp Steel Europe AG

Dr. Karsten Kroos
CEO of the Component Technology ThyssenKrupp AG
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Automotive innovations are created in the field of interaction between weight reduction, cost efficiency and functionality. Competition to find the best technical solutions is taking place against the backdrop of the ever intensifying climate debate, rising demands for comfort from end customers and increasingly strict national and international legislation.

This competition is subject to growing cost pressure. With development cycles shortening dramatically, today it is not just functional and economic aspects that decide the success of new concepts but above all the speed with which these concepts can be introduced into production.

With InCar®, ThyssenKrupp is facing the challenge of providing its partners in the automotive industry with a broad spectrum of innovative solutions.

InCar® solutions are fully validated and display a high degree of maturity.
technologies. These solutions display such a high degree of maturity that rapid integration into production is possible: solutions for body, chassis and powertrain that can be adapted to different customer goals in terms of weight reduction, cost, functionality, emissions reduction and safety.

To meet these requirements, the development themes considered for InCar® were discussed intensively with customers. To be able to demonstrate the advantages of new InCar® solutions, ThyssenKrupp also developed a high-quality reference structure. This reference structure is manufacturer-neutral and guarantees implementability of the innovative InCar® concepts – regardless of differences in manufacturers’ brand, design and production strategies. All innovations are validated in terms of structure performance and manufacturability.

In addition, material, tooling and manufacturing costs are precisely quantified. With this approach, InCar® will allow automotive manufacturers to make a major innovation leap and at the same time reduce the time and cost needed to introduce new technologies into production.

InCar® offers more than 30 innovative body, chassis and powertrain solutions. Whether the objective is weight reduction, cost efficiency or functionality: at least one of these aspects is fulfilled with the InCar® innovation and clearly demonstrates an improvement over the current state of the art.

Weight, function or cost:
Regardless of where automotive OEMs are looking to make improvements, InCar® has the answer. Customers have different innovation priorities and InCar® provides alternatives. For most of the parts and assemblies considered in the project, several innovative solutions are available to meet requirements of lower costs, lower weight or increased functionality.

By using a manufacturer-neutral benchmark, it is possible to assess the effects of different technologies and materials objectively under the same conditions. As a result, InCar® is a modular kit from which customers can select the most suitable solution for their specific requirements.
The InCar® reference structure provides a consistent and ambitious benchmark.

The benchmark for assessing new parts is a high-quality vehicle structure. It is manufacturer-neutral and its design is based closely on real production vehicles from the upper mid-size segment. This market segment is regarded as an innovation driver in the automotive industry. The vehicle style is a station wagon, the style frequently used as a lead vehicle from which further versions are derived.

With a lightweight index of 2.8 the structure is among the best-in-class. All safety requirements are met in full; the reference structure has the potential for a five-star Euro-NCAP rating. In analyzing crash performance, not just current test standards were applied but also those expected in the near future. The reference structure meets both European and US standards.

The reference points for the chassis and powertrain solutions developed in the InCar® project are parts, modules and systems that represent the current state of the art. Here too, the aim was to meet and exceed high quality standards and demonstrate the implementability of the InCar® innovations in a plausible way.

The static performance characteristics of the InCar® reference structure are equal and in some cases superior to the state of the art in 2009.
Marketable innovations with a high degree of maturity call for both creativity and a systematic customer focus. From more than 400 ideas for innovations in automotive manufacture, our researchers, designers and key account managers selected the most promising concepts. These were subsequently discussed with international automotive manufacturers. The focus of the research and development work was finally decided in workshops attended by development and program managers of our customers.
Validated: Production feasibility and cost efficiency

Experts from the ThyssenKrupp Group specialized in materials development, engineering, part production, and equipment, prototype and tooling manufacture for the automotive industry worked together in the InCar® team on an interdisciplinary basis: a reliable basis on which to validate the cost efficiency and production viability of the newly developed InCar® solutions.

InCar® sets standards when it comes to making an economic assessment of automotive innovations. All parts as well as the full assembly were subjected to a comprehensive cost analysis based on current material, equipment, tooling and manufacturing costs. The developers also set themselves high standards for validating the production feasibility of the InCar® solutions. More than 80% of the parts were extensively simulated and optimized for production. The virtual development work was then realized in hardware with prototype body parts manufactured in more than 60 gray iron and plastic dies. A further almost 300 parts were hand-produced as samples.
InCar® provides reliable costs and manufacturing information.

The structural and crash performance as well as durability of the newly developed parts were tested both virtually and in hardware tests, for example drop tower and dent resistance tests. Powertrain and chassis parts proved their capabilities in tests on engine rigs and in simulators. Operation and joining sequences as well as assembly processes are described in detail for all parts, as are fixturing concepts and the results of tolerance investigations. Corrosion protection and paintability aspects for body parts were also clarified with reference to prototypes.
Comprehensive: CO₂ assessment

Automotive innovation is about more than technology and costs. That’s why InCar® also highlights the ecological aspects of the newly developed components and systems. All new InCar® solutions, as well as the reference structure, were systematically analyzed and assessed for CO₂ emissions by an independent institute. The analysis, which was verified by TÜV Nord, covered the entire product lifecycle in each case and complied with the environmental management standard ISO 14040/44, allowing the ecological impact of the new technologies, products and processes to be reliably predicted at an early stage.

Combining the ‘greenest’ new developments from the InCar® project could reduce CO₂ emissions per kilometer by up to 17.63 g. Based on the European Union CO₂ regulation this corresponds to a potential avoidance of penalty payments for excess emissions to the tune of 1,435 euros per vehicle. Over the full cycle there is a reduction of around 5,500 kilograms of CO₂ equivalent per vehicle.

“The CO₂ assessment creates transparency for climate protection in automotive development.”
Potential – Reduction in vehicle emissions
Reduction in CO₂ emissions during driving with a combination of solutions with the lowest lifecycle greenhouse gas potential

<table>
<thead>
<tr>
<th>Body</th>
<th>Chassis</th>
<th>Powertrain</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 2.42</td>
<td>- 1.14</td>
<td>- 14.07</td>
<td>- 17.85 g/km</td>
</tr>
</tbody>
</table>

Penalty in Euro per vehicle for exceeding the EU CO₂ limit by the amounts shown in the diagram on the left

<table>
<thead>
<tr>
<th>Body</th>
<th>Chassis</th>
<th>Powertrain</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>€ 31*</td>
<td>€ 7*</td>
<td>€ 1.09*</td>
<td>€ 1,435*</td>
</tr>
</tbody>
</table>

* Penalties calculated in accordance with EC 443/2009 (due to differences in penalties for exceeding CO₂ limits per gram depending on overall excess, the individual penalties for body, chassis and powertrain cannot be added together into one overall amount.)

A presentation with this structure has been drawn up for each individual new development under the InCar® project: The greenhouse gases arising during part production, the CO₂ emissions arising during use, and total lifecycle emissions are documented and related to the reference. A monetary assessment of emissions is also made, based on the penalty payments for excess emissions established by the EU CO₂ regulation.

The lifecycle assessment takes into account all emissions during production, use and recycling. It also includes associated processes such as the production of raw materials and operating materials. This assessment supplies valuable decision-making help for comprehensive climate protection in automotive manufacturing going beyond the emissions arising during use of the car.
The solutions

InCar® does not just offer one solution but more than 30 – for body, chassis and powertrain. Each solution delivers clear advantages versus the reference in at least one criterion – cost, weight or function. A selection is provided on the following pages. It shows a wide spectrum, as well as the standards and the quality of the results of the InCar® project. The InCar® special issue of ATZ magazine (Automobiltechnische Zeitschrift) in November 2009 provides a detailed presentation of all InCar® innovations.
LCK II: Lightweight chassis concept made of high-strength steel

LCK II, the InCar® rear axle concept, uses the potential of high- and ultrahigh-strength steels for weight-optimized chassis structures. Compared with the InCar® reference, an aluminum rear axle beam, the lightweight chassis concept II delivers the same performance at around 50 percent lower cost, while weighing only four percent more. In the lifecycle assessment, the LCK II permits savings of around 120 kilograms CO₂ equivalent per vehicle.

High-strength steels allow cost-efficient weight reduction in the chassis area.

The LCK II is made from the hot-rolled complex-phase steel CP-W® 800. With a yield strength of 680 megapascals (MPa) this material is significantly stronger than the steels previously used in chassis design. It allows parts to be designed with thinner walls to reduce weight. In addition to the innovative material concept, a further highlight is the use of square butt welds to join the parts: Avoiding welding flanges and the resulting optimized use of package space allows further weight savings. The laser hybrid welds last at least twice as long as MAG-welded joints.

The rear axle in the LCK II concept has been validated in terms of manufacturability and prototypes have been produced in small volumes. A tooling method matched to the high strength of the material and the complex shape of the parts is available. A tooling method was developed to meet the tolerances required for flangeless welding.

Despite reduced material thicknesses, the target rigidity values for the LCK II are in the range of the reference structure. The concept offers equivalent corrosion protection; the complex-phase steel is suitable both for batch galvanizing and for processing in pre-coated form. The LCK II rear axle has demonstrated good durability on a multi-axis testing rig in accordance with common standards.

In addition to the savings already demonstrated, the LCK II concept has the potential for even further reductions in weight and cost: For example, the newly developed multiphase steel TPN-W 780 has a similar yield strength to CP-W® 800 but 30 percent better total elongation. This would allow even more complex shapes and greater functional integration. New coating systems such as the zinc-magnesium surface protection offer potential for further significant cost savings.
DampTronic® select: Sport suspension at the touch of a button

ThyssenKrupp’s DampTronic® select damper closes the gap between complex electronically adjustable damping systems and conventional shocks, providing enhanced user comfort at low cost.

Tight, sporty handling or greater comfort: To date, automotive manufacturers offering customers a choice of different suspension tunings have used continuously variable shock absorbers. This solution requires sensors which detect the movements of the body and wheels, and control units which process the data from the sensors and adjust the shocks on the basis of complex algorithms. The adjustable dampers available at present are highly complex, expensive systems which are difficult to integrate.

The two-stage DampTronic® select damping system developed under the InCar® project demonstrates how customers can be offered the advantages of adjustable dampers at low cost. The damper can be switched between a normal tuning and a tight sport tuning via a dash-mounted button. DampTronic® select offers high customer value at attractive costs and closes the gap between conventional shocks and complex electronic adjusting systems. The two-stage damping system is 70 percent less expensive than continuously variable systems.

The center of the system is the DampTronic® select valve. It provides the driver with a normal setting and, at the touch of a button, a sport setting. The change is controlled by an electromagnet. If the magnet is activated, the two inner valves are connected in parallel and provide a comfortable suspension setting. If the driver wants sporty tuning, he switches the electromagnet off. The system is robust, low in cost and can be adapted to a wide variety of vehicles.

The design of the DampTronic® select valve is the result of extensive tests on the flow test rig. In parallel, FEM analysis was carried out on the individual valve components. In a subsequent prototype phase, the system met all requirements.

Driving tests allowed suitable characteristics to be tuned very quickly. Durability was demonstrated in trials on shock absorber test rigs. The system is also designed for use on vehicles with McPherson front axles and is adapted to common damper diameters. The length of the DampTronic® select has been reduced to the technical minimum; the system requires only 20 mm more package space than common conventional dampers.
Presta Integrated Cam Assembly (PICA): Innovative camshaft mounting makes cylinder heads cheaper and lighter

A new camshaft module from ThyssenKrupp saves up to ten euros in cylinder head machining, reduces weight by more than a kilogram and reduces valve train friction by up to ten percent.

Subsequently the bearing caps need to be removed again to allow the camshaft to be fitted.

In the new InCar® solution the bearing blocks are mounted directly on the camshafts. The bearing block modules surround the shafts fully and are flat-bottomed for simple mounting on the cylinder head. The complex process of assembling the bearing caps machining the bearings, subsequently removing the bearing caps, inserting the camshaft and reassembling the caps is eliminated. This concept also reduces the height and complexity of the cylinder head leading to reduced weight and costs.

The camshafts are mounted in one-piece bearings, therefore there is no offset which can lead to the tearing of the oil film in the bearing. Selecting the optimum material for the bearing blocks also reduces temperature-dependent changes in the lubricating gap, which reduces the requirements on the oil pump.

In addition, the bearing blocks can be used with one-piece needle or ball bearings, reducing valve train friction by up to ten percent compared with the reference.

Temperature-dependent finite element analyses were used to optimize bearing deformation and stresses based on the bolt-on forces and cam torques. Material behavior under load was tested in a multiple-body simulation of the camshaft system, coupled with an elastohydrodynamic analysis. Part tolerances were also subject to systematic and cost-appropriate optimization using corresponding simulation tools.

The integrated bearing blocks are suitable for assembled camshafts – steel tubes with individually mounted components. Integration of the bearing blocks requires only a minor modification to the standard assembly process. It was demonstrated that mounting of the modules can be automated. Successful tests have been carried out by customers on running engines.

Presta Integrated Cam

- 1 kg
- 10 euros
- 10% Function*

Reference: Camshafts with conventional splitted journal bearings
four-cylinder DOHC, aluminum cylinder head with bearing caps

*friction loss in valve train

Powertrain
Cost-optimized Solution

Ten euros less expensive, more than one kilo lighter and up to ten percent less friction

The reference for this concept is a normal four-cylinder DOHC cylinder head. Current state of the art cylinder heads feature split bearing caps. The cylinder head bearings must be machined whilst the bearing caps are bolted in position.
The Advanced Door from ThyssenKrupp offers an eleven percent weight reduction and improved crash performance at no additional cost. It features a highly integrative door inner panel and a thin, light outer skin of high-strength dual-phase steel. Its environmental performance: up to 109 kilograms less CO₂ equivalent per vehicle compared with the reference.

The developers took a whole new approach with the door inner panel. The conventional one-piece solution was split lengthwise from top to bottom to form an inner part and an outer part.

The outer inner panel combines virtually all reinforcement parts, including the side intrusion beam, the hinge and lock reinforcements, the lower crash reinforcement and the outer waist reinforcement.

The advantage: Several single parts and joining operations are no longer necessary and assembly requirements in the BIW line are significantly reduced. The formability and strength of the part were validated in FEM simulations.

The outer inner panel can be manufactured from a high-strength tailored blank made of either hot-stamping steels or high-strength cold-stamping materials.

The outer and inner door panels are joined by laser beam stitch welding, starting above the drain holes. In addition, the structure has been designed to minimize contact areas and guarantee optimized deposition of the electrocoating.

The new thin sheet outer skin of the Advanced Door accounts for seven percent of the eleven percent weight reduction: The developers used a 0.55 mm thick sheet, 0.2 mm thinner than the reference structure. The material is a high-strength dual-phase steel which has a comparatively high yield strength of 300 megapascals. Two additional struts in the outer door inner panel provide further protection against dentsing.

The crash performance of the Advanced Door was calculated for relevant load cases for both the hot-stamped and cold-stamped versions. Both significantly outperformed the reference solution. Taking into consideration the design measures and using secondary corrosion protection, the requirements of the VDA-621-415 cyclic corrosion test were also met.
Hot stamping developed further: Tailored tempering for B-pillars

Tailored tempering is a further development of the hot stamping process in which parts can be produced with different strengths and elongation properties in different zones. In the InCar® project this technology was used to produce prototype B-pillars using the newly developed hot stamping steel MBW® 1900. At 1,900 megapascals (MPa) this material delivers 400 MPa higher component strength than the previously available hot stamping steels.

A B-pillar was produced which delivers the same crash performance as the reference but is 22 percent lighter and costs nine percent less. The new solution reduces lifetime emissions of CO₂ equivalent by 122 kilograms per vehicle.

Tailored tempering is a new method of producing weight-optimized B-pillars with good crash performance from a single sheet of hot stamping steel. In the hot stamping process, sheets of manganese-boron steel are first heated to 880 to 950 degrees Celsius, then formed on a special press followed by rapid cooling in the same die. This gives the material a very hard microstructure.

With tailored tempering, a temperature-controlled hot stamping die is used. In this case, only the upper part of the B-pillar is cooled rapidly during forming to give it extremely high strength and low elongation, as in conventional hot stamping. In the base area of the pillar, the die is heated so that this zone cools more slowly. The increase in strength is correspondingly lower, and the part displays greater elongation in this area.

The InCar® B-pillar produced by tailored tempering has an elongation of 15 percent and a tensile strength of 700 MPa in the base area. In the upper area, tensile strength is 1,900 MPa and elongation around five percent.

The crash performance of the B-pillar has been validated virtually and in the InCar® reference structure. All results were in the same range as the reference; the particularly stringent requirements of the US IIHS side impact load case are met in full.

Dimensional accuracy, energy absorption capacity and buckling safety were tested on prototypes.

Tailored tempering produces locally different, load-oriented material properties – for optimum weight reduction.

<table>
<thead>
<tr>
<th>B-pillar tailored tempering</th>
<th>Weight</th>
<th>Cost</th>
<th>Function*</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBW® 1900</td>
<td>-22%</td>
<td>-9%</td>
<td>-17% CO₂ emissions (during use)</td>
</tr>
</tbody>
</table>

Reference: DP-W® 600 DP-W® 600 2.2/0.20 mm; 18.67 kg/vehicle
27 percent lighter, 13 percent less expensive: Longitudinal member as $T^3$ profile

The InCar® concept for front longitudinal members offers savings of up to 27 percent on weight and up to 13 percent on costs. It is based on the $T^3$ technology developed by ThyssenKrupp for tubular parts. The new solution reduces emissions of CO$_2$ equivalent by up to 126 kilograms per vehicle. The benchmark for the new longitudinal member concept is a two-part stamped and welded design made from high-strength dual-phase steel in the InCar® reference structure.

$T^3$ technology is an innovative process for the production of tubular profiles with varying crosssection over their length and integrated secondary design elements. $T^3$ technology permits the integration of several individual parts and process steps.

For example, after forming the tubular longitudinal member already features two beads, two positioning holes and flanges at the front end. It is made from tailored blanks with varying thickness.

"Tubular designs are an important component of lightweight steel design and allow weight reductions of more than 25 percent."

To demonstrate the potential of $T^3$ technology, the developers first manufactured a longitudinal member from the same dual-phase steel as used in the reference. The geometrical advantages of the tubular design compared with the stamped and welded solution deliver a weight saving of 16 percent and cost savings of 11 percent. The weight and cost advantages increase to 27 percent and 13 percent respectively if the newly developed ultrahigh-strength multiphase steel TPN-W 780 is used and the material thickness correspondingly reduced.

The forming behavior of both parts was tested on the basis of forming simulations and an extended failure analysis using CrashFEM. The structural properties have been validated, also with a view to the global stiffness of the body structure, the local stiffness of the axle attachment and the natural frequencies.

To facilitate the integration of tubular parts into body assembly, the development team came up with a longitudinal member module suitable for resistance spot welding. This development included the selection of suitable assembly technologies and the definition of an assembly sequence and a fixturing concept for the complete longitudinal member module. Close-to-production solutions were also elaborated for the insertion of bulkheads in the tubes.

The longitudinal member module made from dual-phase steel has been manufactured as a full hardware version, while the TPN solution was validated virtually.

<table>
<thead>
<tr>
<th>$T^3$ longitudinal member</th>
<th>Weight</th>
<th>-27%</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPN-W 780</td>
<td>Cost</td>
<td>-13%</td>
</tr>
<tr>
<td></td>
<td>Function*</td>
<td>-22%</td>
</tr>
</tbody>
</table>

*CO$_2$ emissions (during use)

Reference: DP-W® 600
Inner longitudinal member DP-W® 600 1.80/2.00 mm and outer longitudinal member 1.80 mm; 15.56 kg/vehicle

Body Weight-Optimized Solution

Tubular designs are an important component of lightweight steel design and allow weight reductions of more than 25 percent.
Numerous variants: Magnesium roof module

The InCar<sup>®</sup> magnesium roof offers weight savings of the highest level: At only 8.94 kilograms, the roof module is 62 percent lighter than the steel benchmark.

In the high-end segment, the magnesium roof offers cost advantages above all in competition with similarly lightweight solutions made from carbon fiber reinforced plastics (CFRP).

The magnesium roof module meets all common crash requirements and its rigidity values are comparable with those of the reference structure. Production feasibility has been validated through FEM simulations, extensive tryouts and pre-production prototyping. Possible joining techniques include both the common spot, MIG and laser beam welding methods as well as the usual cold joining techniques such as riveting, thread fastening and adhesive bonding.

To compensate for the different rates of thermal expansion of steel and magnesium, the roof module is adhesively bonded with the body and additional threaded fasteners are provided in the area of the B-pillar joint. This metal joint can be protected for example by a self-adhesive dirt seal.

Different variants of the magnesium roof, e.g. with sun roof, can be integrated into various bodies without difficulty. The assembly comprises a six-part frame structure and an outer panel, both of which are separately provided with a ceramic coating to protect against stone chipping before being joined together. The magnesium roof module can be fully manufactured by suppliers and fed into the OEM’s assembly line prior to painting. The concept offers not only a high level of variant flexibility but also opportunities for further product integration. For example, the module can be manufactured by the supplier with all interior fittings. This allows even greater cost reductions for the roof module in the process chain.

### Table: Body Weight-optimized Solution

<table>
<thead>
<tr>
<th>Magnesium roof module</th>
<th>-62%</th>
<th>Weight</th>
</tr>
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<tbody>
<tr>
<td>82%</td>
<td></td>
<td>Cost</td>
</tr>
<tr>
<td>-52%</td>
<td></td>
<td>Function*</td>
</tr>
</tbody>
</table>

Reference: Conventional design
Outer skin BHZ 180, 0.90 mm; 19.31 kg
Module scope (outer skin plus crossmember 23.68 kg)

*CO₂ emissions (during use)
Roof made of sandwich material with improved stiffness: Meeting ambitious weight reduction targets at low cost

Two thin steel sheets and a polymer core – those are the ingredients of the new roof outer panel made from a stiffness-optimized sandwich material. The solution is attractive from both weight and cost perspectives. And despite its low weight, stiffness and crash performances match the high level of the reference structure. Suitable common processes for joining the sandwich roof to the body have been identified.

The newly developed roof of stiffness-optimized sandwich material is 38 percent (7.29 kilograms) lighter than the steel roof in the InCar® reference structure. Total costs are around 33 percent higher than for the conventional steel reference roof. The lightweighting costs for the sandwich roof amount to an attractive 1.35 euros per kilogram.

The stiffness-optimized sandwich material comprises 0.20 and 0.30 millimeter thick face sheets firmlybonded by a 0.40 millimeter thick polymer core. The sandwich roof is thus exactly the same thickness as the reference roof. The polymer core has a density of 1.03 grams per cubic centimeter.

Innovative sandwich material makes large outer skin parts significantly lighter.

The sandwich roof is attached to the body by self-piercing riveting and, like the reference structure, by laser brazing. The feasibility of such joints was confirmed in intensive tests.

One of the most important test findings: For laser brazing on a production scale it is recommended that asymmetrical sandwich sheets be used.

The thicker face sheet should be on the outside to provide reserves for the material removed during standard finishing of the brazed seam.

Test series showed that increasing the thickness of the upper face sheet by 0.1 millimeters provided sufficient scope.

The sandwich material can also be used for other outer skin solutions such as hoods, doors, fenders and lift gates. Other applications include the rear window shelf and floor panels. Depending on application, steel sheets with different thicknesses and grades and different plastic interlayers can be combined.
Integrated steering: Smaller package, lower weight, lower cost

One plus one equals one: That’s the math if you add steering know-how and chassis expertise at ThyssenKrupp. The newly developed integrated steering system shows how intelligent part integration can save eleven percent weight and also reduce package space requirements – while cutting costs by three percent compared with a conventional front axle beam with an electro-mechanical steering system. The new solution lowers emissions of CO₂ equivalent by 85 kilograms per vehicle over the full lifecycle.

In the integrated steering system, the steering gear housing and the crossmember are combined in one part, which together with two longitudinal members forms the basis for a classic U-shaped front axle beam.

In the new InCar® solution, the crossmember has been replaced by a steel housing which accommodates the steering gear and performs the support functions of the crossmember. This integrated design is eleven percent lighter than the reference structure. Part and production costs are reduced by three percent, mainly because the aluminum steering housing is dispensed with.

The structural performance of the integrated steering system matches that of the reference structure. The assembly actually delivers six percent improved stiffness. Tests on fatigue strength by finite element modeling show that all areas are adequately dimensioned. Based on simulations of various load cases, the integrated steering system has been optimized to such an extent that even under maximum loads, elastic part deformation is in the non-critical range and does not impede steering functions. A production concept for the new integrated steering system has been drawn up.

Combining the crossmember and the steering gear into one component creates new design freedom in the front axle area which can be used, for example, for active stabilizers or hybrid drives.

The developers implemented a further possibility directly: They replaced the hydraulic steering system of the reference with an electro-mechanical steering system, using some of the freed-up package space to accommodate the drive unit. This was the first successful example of integrating a higher-quality steering function into an existing structure without having to modify the size and position of adjacent units.
The Presta Shiftable Valve Control (PSVC) stands for maximum engine performance and minimum fuel consumption. Developed as part of the InCar® project, this control system is designed at least as a three-stage valve lift system. PSVC reduces fuel consumption by two to five percent compared with an already very economical direct-injection 1.4 liter four-cylinder engine used as a reference. In environmental terms, this means that emissions of CO₂ equivalent over the full lifecycle are reduced by 2,265 kilograms per vehicle. In the light load range, cylinder deactivation allows additional reductions in consumption of 8 to 20 percent and further savings on CO₂ emissions.

The additional cost for the valve control on the intake side amounts to 124 euros for a volume of 400,000 four-cylinder engines per year. The system can also be used for smaller engines with cylinder spacing of less than 80 millimeters.

The PSVC system allows intake or exhaust valves to be adjusted in at least three stages between fully open and cylinder deactivation. Lift height, valve speed and valve acceleration can be designed to customer specifications within the normal range. Using PSVC, the volume, composition and utilization of the fuel/air mixture in the cylinder chamber can be optimized in line with engine speeds and loads.

A key characteristic of the PSVC system is the compactness of the adjustment mechanism which is positioned between the camshaft and the cam followers. The adjustment of this mechanism allows for different predefined valve heights to be selected. The position of the mechanism is adjusted using an actuating shaft powered by a small electric motor.

A functioning prototype of the valve control system was manufactured and tested. It can be mounted on an existing cylinder head as a prefabricated assembly, or integrated directly into the cylinder head on new developments. The PSVC components can be produced in high volumes as precision castings and low-cost sheet metal parts. Production and assembly concepts are available.

The excellent performance of the PSVC system has been demonstrated in "non fired" cylinder head tests. The system has been successfully tested and proven reliable at engine speeds of up to 6,000 rpm.

**PSVC: Sustainable CO₂ reduction through shiftable valve control. Also suitable for smaller engines.**

### Powertrain

**Function-optimized Solution**

<table>
<thead>
<tr>
<th>Presta Shiftable Valve Control (PSVC)</th>
<th>Weight</th>
<th>Cost</th>
<th>Function*</th>
</tr>
</thead>
<tbody>
<tr>
<td>(PSVC)</td>
<td>2.8 kg</td>
<td>124 euros</td>
<td>-7.71 g CO₂/km</td>
</tr>
</tbody>
</table>

Reference: Conventional non-variable valve trains
4-cylinder DOHC, aluminum cylinder head with bearing caps

*CO₂ emissions (during use)
Body solutions
01 Front longitudinal member
02 Firewall
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All InCar® solutions – body, powertrain and chassis at a glance.

**General note**

All statements as to the properties or uses of materials or products are for descriptive purposes only. Guarantees in respect of specific properties or uses are only valid if agreed in writing.
### B-pillar

**Reference:** DP-W® 600  
DP-W® 600 2.20/2.00 mm; 18.67 kg/vehicle

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
</table>
| 01 | B-pillar TPN-W 900 | -19%  
-15% |
| 02 | B-pillar DP-K® 60/98 / RA-K® 40/70 | -13%  
-11% |
| 03 | B-pillar hotform blank MBW® 1500/MHZ 340 | -15%  
-12% |
| 04 | B-pillar hotform blank with varying sheet thickness MBW® 1500/MHZ 340 | -18%  
-15% |
| 05 | B-pillar tailored tempering MBW® 1500 | -17%  
-13% |
| 06 | B-pillar tailored tempering MBW® 1900 | -2%  
-17% |

### Front longitudinal member

**Reference:** DP-W® 600  
Inner longitudinal member DP-W® 600 1.80/2.00 mm and outer longitudinal member 1.80 mm; 15.56 kg/vehicle

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<table>
<thead>
<tr>
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</thead>
</table>
| 01 | Longitudinal member tailored blank DP-K®/CP-W®/TPN-K | -16%  
-13% |
| 02 | Longitudinal member tailored blank TPN-K/TPN-W/DP-K® | -22%  
-18% |
| 03 | Longitudinal member TPN-W 780 | -14%  
-11% |
| 04 | T³ longitudinal member DP-W® 600 | -10%  
-13% |
| 05 | T³ longitudinal member TPN-W 780 | -13%  
-22% |

### Roof

**Reference:** Conventional design  
Outer panel of BHZ 180, 0.90 mm; 19.31 kg; scope of module (outer panel plus crossmember 23.68 kg)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</thead>
</table>
| 01 | Stiffness-optimized sandwich roof | 33%  
-33% |
| 02 | Steel roof module | weight-neutral  
functions-neutral |
| 03 | Magnesium roof module | 82%  
-62% |

### Side panel

**Reference:** Conventional side panel  
Multi-part, assembled solutions

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>
| 01 | Inner side panel tailored blank | -3%  
-6% |
| 02 | Side panel reinforcement hotform blank | -3%  
-6% |
| 03 | Reinforcement front door ring tailored blank | -3%  
-3% |

### Firewall

**Reference:** MHZ 340  
Part weight 5.63 kg; 10.03 kg incl. damping and insulating measures

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<table>
<thead>
<tr>
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<th></th>
<th></th>
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</thead>
</table>
| 01 | Firewall BONDAL® CB | -28%  
-23% |

### Hood

**Reference:** Conventional design  
Outer panel BHZ 180, 0.7 mm; 12.39 kg; complete hood 25.13 kg

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>
| 01 | Hood made of sandwich material with improved stiffness | -11%  
-9% |
### Door

Reference: Conventional steel door with tailored blanks  
Total weight 17.17 kg/door or 34.34 kg/vehicle

<table>
<thead>
<tr>
<th>Item</th>
<th>Function</th>
<th>Cost-neutral</th>
<th>Weight-neutral</th>
<th>CO2-emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Advanced Door hot-stamped</td>
<td>11%</td>
<td>-9%</td>
<td>-11%</td>
<td>-9%</td>
</tr>
<tr>
<td>02 Advanced Door cold-stamped</td>
<td>11%</td>
<td>-9%</td>
<td>-11%</td>
<td>-9%</td>
</tr>
<tr>
<td>03 Lightweight steel door</td>
<td>11%</td>
<td>-13%</td>
<td>-11%</td>
<td>-13%</td>
</tr>
</tbody>
</table>

### McPherson strut

Reference: Conventional McPherson strut (plate) 0.46 kg;  
Conventional McPherson strut (tube) 1.25 kg or 2.5 kg/vehicle

<table>
<thead>
<tr>
<th>Item</th>
<th>Function</th>
<th>Cost-neutral</th>
<th>Weight-neutral</th>
<th>CO2-emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Weight-optimized McPherson strut</td>
<td>15%</td>
<td>-14%</td>
<td>-9%</td>
<td>-0.06 g CO2/km</td>
</tr>
</tbody>
</table>

### Twist-beam axle

Reference: Standard RTB (generic)  
Total weight 28.65 kg

<table>
<thead>
<tr>
<th>Item</th>
<th>Function</th>
<th>Cost-neutral</th>
<th>Weight-neutral</th>
<th>CO2-emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Innovative twist-beam axle concept</td>
<td>-14%</td>
<td>-9%</td>
<td>-11%</td>
<td>-14%</td>
</tr>
</tbody>
</table>

### Rear axle beam

Reference: Aluminum rear axle beam  
Total weight 17.20 kg

<table>
<thead>
<tr>
<th>Item</th>
<th>Function</th>
<th>Cost-neutral</th>
<th>Weight-neutral</th>
<th>CO2-emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Lightweight chassis concept II</td>
<td>-50%</td>
<td>4%</td>
<td>-11%</td>
<td>-50%</td>
</tr>
</tbody>
</table>

### Spring

Reference: Conventional hot-wound spring  
Total weight 1.37 kg/spring or 2.74 kg/vehicle

<table>
<thead>
<tr>
<th>Item</th>
<th>Function</th>
<th>Cost-neutral</th>
<th>Weight-neutral</th>
<th>CO2-emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 ThermoTecSpring®</td>
<td>-14%</td>
<td>4%</td>
<td>-11%</td>
<td>-0.03 g CO2/km</td>
</tr>
</tbody>
</table>

### Axle modularity

Reference: Vehicle structure with multi-link rear axle

<table>
<thead>
<tr>
<th>Item</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Axle modularity concept</td>
<td>Studies on the integration of a twist-beam and a multi-link rear axle into a controlled or an uncontrolled body assembly line.</td>
</tr>
</tbody>
</table>

### Camshafts with integrated bearing blocks

Reference: Camshafts with conventional splitted journal bearings  
4-cylinder DOHC, aluminum cylinder head with bearing caps

<table>
<thead>
<tr>
<th>Item</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Presta Integrated Cam Assembly (PICA)</td>
<td>-1 kg, -10 euros, -10%*</td>
</tr>
</tbody>
</table>